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SPACE SCIENCES LABORATORY

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AN INTEGRATED STUDY OF EARTH RESOURCES IN THE STATE OF CALIFORNIA BASED ON ERTS-1 AND SUPPORTING AIRCRAFT DATA

A report of work done by scientists on 5 campuses of the University of California (Davis, Berkeley, Santa Barbara, Los Angeles and Riverside) under NASA Contract No. NAS 5-21827

E73-10027

Progress Report
September 30, 1972

UNIVERSITY OF CALIFORNIA

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October 25, 1972

Mr. Edward W. Crump
Technical Monitor
Code 430
NASA-Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Ed:

Attached please find a copy of our first ERTS-1 Type 1 Progress Report for the NASA-funded project entitled, "An Integrated Study of Earth Resources in the State of California Based on ERTS-1 and Supporting Aircraft Data". No published material based on our study has been released during this reporting period, although a typewritten version of the material which I presented at the Goddard briefing on September 29, 1972 was given to Dr. Nordberg at that time.

During this reporting period one change has been made in the standing order forms (i.e., UN 326, September 28, 1972).

Five data request forms have been submitted during this same period. Four of these were for UN 257 and were made on August 10, 1972. The fifth one was for UN 326 and was made on September 25, 1972.

Sincerely,

Robert N. Colwell

Robert N. Colwell
Principal Investigator

Details of illustrations in this document may be better studied on microfiche

RNC:jef
Enclosure

cc: Mr. I. G. Poppoff, Scientific Monitor, w/enclosure

Original photography may be purchased from:
EROS Data Center
10th and Dakota Avenue
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Chapter 1

INTRODUCTION

Robert N. Colwell

A large number of federal, state and private agencies currently are investigating the usefulness of ERTS-1 data for the making of resource inventories in California. These include the U.S. Forest Service, the Bureau of Land Management, the University of California, several agencies within the Administrative Branch of the State of California (including the California Department of Agriculture and California Resources Agency), and such private industrial groups as Earth Satellite Corporation, IBM Corporation and Natural Resources Management Corporation.

The present report pertains to work that has been performed to date by personnel of the University of California. Our NASA-funded study involves participation by scientists from 5 campuses of the University and seeks to make an integrated study of earth resources in the state of California using ERTS-1 and supporting aircraft data.

The possibility is recognized of achieving two kinds of benefits from this study: (1) some of the ERTS-based resource inventories should prove to be of direct and immediate benefit operationally to the managers of California's earth resources, even though ERTS-1 was intended to serve only as an experimental system, and (2) resource inventory techniques developed and tested in California should prove to be applicable, with only minor modification, to many analogous areas in developing parts of the globe.

By July 25, 1972, less than 48 hours after ERTS-1 had been launched it was obtaining operationally useful data of vast portions of the state of California. In fact, cloud-free coverage of nearly half of the state was obtained during the three passes made over California by ERTS-1 on July 25, 26 and 27.

From the outset our group has made a maximum effort to ensure that the analyses which we made of ERTS imagery would be responsive to the expressed needs of the resource managers, themselves. Collectively the various "user groups" with which we are working are representative of most of the resource managers of the state of California. Long before the launch of ERTS-1, and in anticipation of its potential usefulness as a resource inventory tool, we were working closely with these groups. This previously established relationship has greatly facilitated our working in a meaningful way with these same groups during the limited period of time that actual ERTS-1 imagery has been available to us. We are confident that our findings to date, as reported in the remainder of this Progress Report, are much more than mere pleasant discoveries as to the kinds of features that are discernible on ERTS-1 imagery. Instead they are truly responsive to the needs of these various groups for timely, accurate information relative to the resources which they seek to manage.

Chapter 2

REGIONAL AGRICULTURAL SURVEYS USING ERTS-1 DATA (UN640)

Co-investigator: Gene A. Thorley
Contributors: William Draeger, Jim Nichols
Forestry Remote Sensing Laboratory, Berkeley Campus

Considering the present needs for regional, national, and worldwide inventory and evaluation data, coupled with the particular capabilities of the ERTS system, agricultural applications would seem to be especially promising as an area in which important benefits might be realized from the use of such technology. In the United States, the Department of Agriculture presently conducts an enumerative program in which virtually all agricultural land is inventoried annually. In addition numerous other federal, state and local agencies conduct extensive crop inventories, land use surveys, and soils mapping projects of varying magnitude. On a worldwide basis it would seem that the principal obstacles to providing enough food for all persons are those of allocation and distribution. What is needed is knowledge as to where and how much food is now being produced, and how crop production is changing with time.

In all cases, these inventories require a tremendous effort on the part of on-the-ground enumerators, and present a formidable data compilation task. This suggests that a satellite sensing system, with which large areas of land can be surveyed in their entirety on one image, and which could provide worldwide coverage with a relatively small number of images, could be extremely valuable as a data collection tool. Furthermore, the dynamic nature of agriculture requires not a single evaluation in most cases, but rather a continual updating of conditions. In fact, it has been shown that desired information about agricultural crops can often be obtained only by capitalizing on a knowledge of the patterns of change of particular crop types of conditions. Again, this suggests that a satellite sensing system such as ERTS, which makes possible regular, frequent observations of each spot on the earth's surface, can provide a service which would be totally infeasible using conventional techniques.

Based on these facts, plus the encouraging results achieved using both high altitude aircraft and spacecraft imagery for crop inventory experiments over the past several years, the Forestry Remote Sensing Laboratory at the University of California has been funded by NASA to perform an experiment designed to evaluate the feasibility of using ERTS-1 type data to provide needed agricultural information on an operational basis for regional areas. This experiment, conducted in cooperation with a number of state and federal agencies (see Table 2.1), is being performed in Maricopa County, Arizona and San Joaquin County, California.

In an effort to accurately determine the degree of detail which can be extracted from ERTS-1 data, and the optimum use of "subsampling" in the form of aerial photography and ground truth data for various agricultural-related tasks, the investigation is being carried out in a step-wise fashion beginning with gross land use mapping, and progressing

TABLE 2.1 USER AGENCY COOPERATION
AGRICULTURAL APPLICATIONS PROJECTS

USER GROUP AGENCY	PERSONAL CONTACTS	REMOTE SENSING APPLICATION
USDA, STATISTICAL REPORTING SERVICE, CALIFORNIA CROP AND LIVESTOCK REPORTING SERVICE	MR. WARD HENDERSON MR. WENDELL WILSON	CLASSIFICATION OF AGRICULTURAL LAND (STRATIFICATION); CROP ACREAGE INVENTORIES
USDA, AGRICULTURAL STABILIZATION AND CONSERVATION SERVICE. BUTTE COUNTY, CALIFORNIA	MS. DARLYS COPE	SUBSIDY AND ALLOTMENT PROGRAM COMPLIANCE MONITORING
CALIFORNIA DEPARTMENT OF WATER RESOURCES, PLANNING STAFF	MR. BARRY BROWN	WATER CONSUMPTIVE USE REQUIREMENT MONITORING IN AGRICULTURAL AREAS
DEPARTMENT OF WATER RESOURCES, CENTRAL DISTRICT	MR. ARTHUR DE RUTTE	DETECTION OF LAND USE CHANGE AND AGRICULTURAL YIELD REDUCTION DUE TO HYDROLOGIC PROJECTS
UNIVERSITY OF CALIFORNIA, AGRICULTURAL EXTENSION SERVICE	MR. WILLIAM WILDMAN	GENERAL AGRICULTURAL EVALUATION AND LAND MANAGEMENT PLANNING

to very detailed surveys. Three sub-tasks being performed are as follows:

Delineation of Agricultural Land: An evaluation of the accuracy with which agricultural areas can be differentiated from other land use categories on a periodic (e.g., semi-annual) basis. Such information is necessary for the monitoring of land use change and for the planning of more detailed surveys. In addition this sub-task attempts to assess the feasibility of preparing graphic materials which illustrate the areal extent of agricultural land, and the changes which have taken place in land use semi-annually.

Classification of Agricultural Land: An assessment of the feasibility of performing periodic tabulations of the predominant agricultural use of each square mile of land within each of the general agricultural areas delineated in sub-task 1. This sub-task entails a breakdown of agricultural areas into general crop type or use groups suggested by the cooperating user agencies as being of particular interest.

Crop Inventory: A determination of the accuracy with which the acreage of selected crops (e.g., barley, wheat, and cotton) can be estimated.

In each of the sub-tasks listed above, emphasis is placed on obtaining a quantitative expression of the accuracy of estimates obtained by the use of remote sensing for the county as a whole, and where possible, a comparison of these results with those obtained using conventional techniques. Investigations entail the use of both human interpreters and automatic classification and data handling techniques, and an evaluation of the optimum mix of human and machine techniques for each analysis problem. In each case, an attempt is made to ensure that the types of information compiled (e.g., maps, tabular data, crop acreages, etc.) conform to actual requirements or desires as expressed by those persons currently involved in resource evaluations and planning in the test site.

The preliminary stages of the investigation, which are described in this progress report, represent an initial attempt to evaluate the usefulness of ERTS-1 data for performing these three sub-tasks.

2.1 PROCEDURES AND RESULTS

2.1.1 Agricultural Land Use Classification

An attempt was made to stratify all land within San Joaquin County into broad land use and crop category classes based on their appearance on the ERTS-1 color composite image. These stratifications were then evaluated by comparison with ground data collected on 48 permanent 4-square-mile cells established as a basis for "ground truth" in the county, and with stratifications and land use maps prepared by a number of other state and federal agencies. It was hoped that this initial evaluation would give at least some indication as to the potential for performing operational land use and agricultural stratifications directly on the ERTS-1 images.

The stratification of the agricultural land use categories proved to be a relatively simple task, taking each of three interpreters approximately 30 minutes to complete. The three interpretations were quite similar, requiring only minor revisions to produce a "consensus" stratification. A total of fiteen different agricultural strata were recognized, differing both in general field size and relative proportions of crop types and degree of irrigation. Upon comparing these interpretations we concluded that nearly all boundaries were truly representative of differing cropping practices. In a number of cases, the stratifications agreed almost exactly with soil type boundaries as drawn by earlier soils surveys, and in many cases probably represent a refinement of those earlier boundaries drawn "in the field".

Figure 2.1 illustrates the strata boundaries as drawn on the ERTS-1 photograph, while Table 2.2 presents a description of each of the strata categories in terms of land use and cropping practices. In Figure 2.2, the strata as drawn on the ERTS-1 photo can be compared with a land use and crop map of San Joaquin County which was compiled at the time of the 1952 soil survey for the county. Differences in the two maps may be due in part to (1) changes that have taken place since 1952, (2) inaccuracies in the 1952 map, and (3) the inability of the interpreters to detect all meaningful land use patterns on the ERTS-1 image.

It was also noted that the stratifications derived from the ERTS-1 image provide a much more detailed, accurate, and up-to-date basis for crop inventory sampling as carried out by the Statistical Reporting Service, U.S. Department of Agriculture, than is currently available to that agency. This alone could result in a considerable increase in the accuracy of crop acreage estimates, and savings in the cost of field

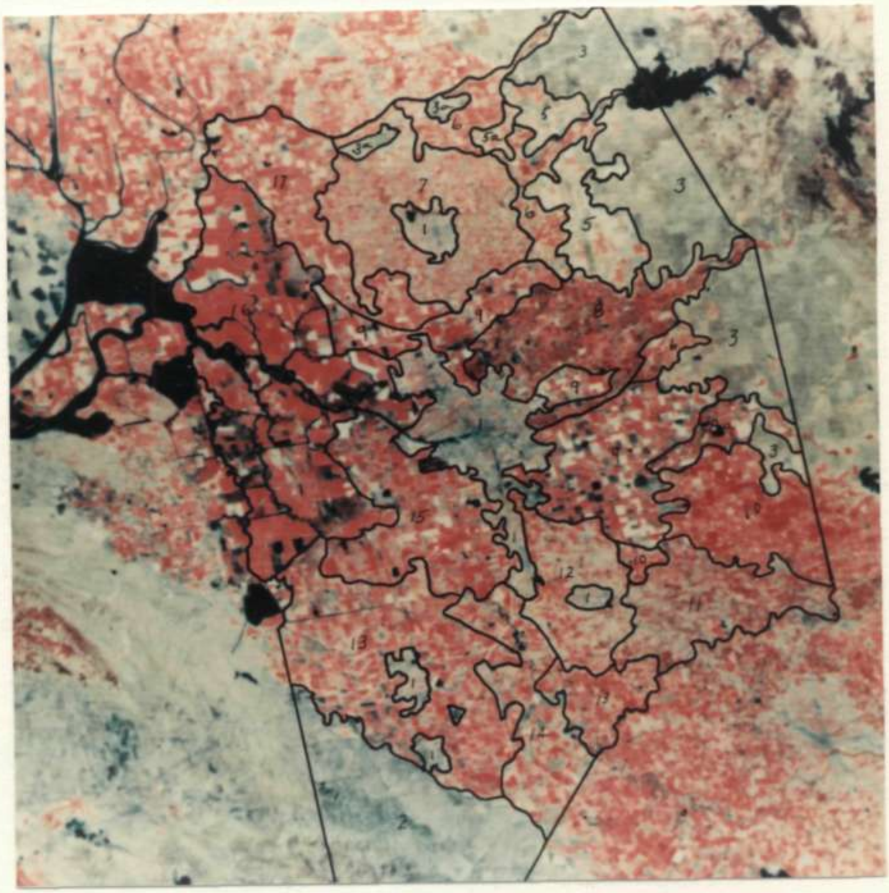

Figure 2.1 Enlarged portion of an ERTS-1 MSS color composite taken on July 26, 1972, showing stratification of land use categories within the San Joaquin County test site. For a description of strata classifications, as numbered on this photo, see Table 2.2.

TABLE 2.2

DESCRIPTION OF STRATA CLASSIFICATIONS

Stratum #	Major Land Use	Major Crops	Secondary Crops
1	urban and non-agriculture	none	some orchards and pastures
2	range	native grassland	none
3	range	native and improved grassland	some irrigated pasture and dry land grains
4	urban and non-agriculture	water storage	recreation
5	pasture and grains	range and irrigated and non-irrigated improved pastures and dry land grains	vineyards and orchards
6	pasture and grains	irrigated pasture	fruit orchards and vineyards, field crops
7	orchards and vineyards	vineyards	fruit and nut orchards, minor field crops and irrigated pasture
8	orchards and vineyards	fruit and nut orchards	field crops
9	pasture and grains	grains and field crops	irrigated pasture
10	pasture and grains	irrigated pasture	field crops, fruit and nut orchards
11	orchards and vineyards	nut and fruit orchards	vineyards, irrigated pasture
12	orchards and vineyards	vineyards, orchards	irrigated pasture
13	field crops	asparagus, sugar beets, alfalfa, beans, grains, safflower	tomatoes
14	field crops	grains, alfalfa, sugar beets	other field crops
15	field crops	grains, alfalfa, sugar beets, tomatoes	other field crops
16	field crops	asparagus, corn, alfalfa, sugar beets	other field crops
17	pasture and grains	irrigated pasture, alfalfa, grains	sugar beets, vineyards

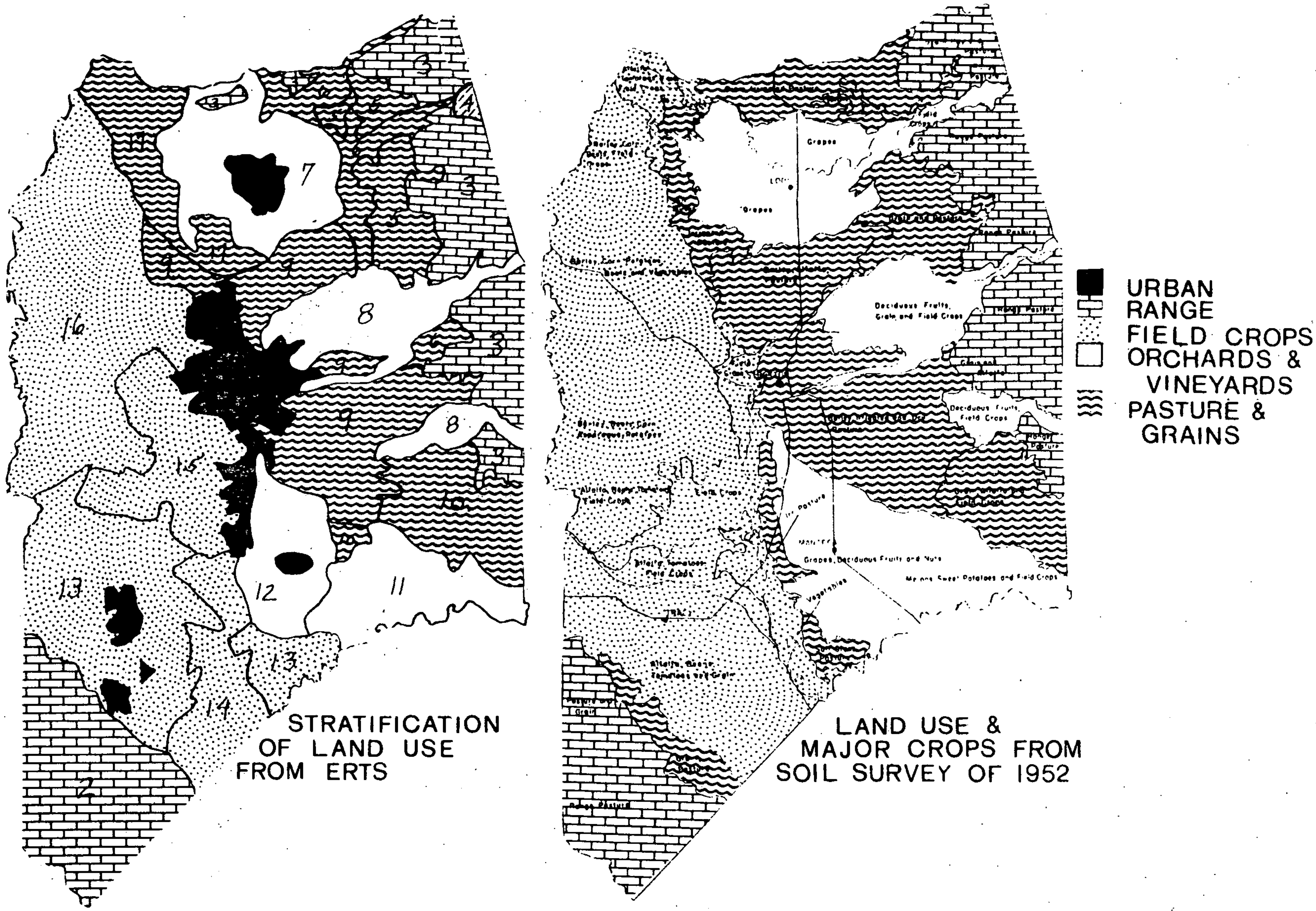

Figure 2.2 Comparison of agricultural stratification of the San Joaquin County test site as interpreted on an ERTS-1 color composite with the generalized land use and major crop map from the 1952 Soils Survey of San Joaquin County.*

*Weir, Walter W. 1952. Soils of San Joaquin County, California. University of California, College of Agriculture, Agricultural Experiment Station. Berkeley, California. June.

work. In San Joaquin County, the California Crop and Livestock Reporting Service currently uses a general land use stratification system in its annual enumerative surveys. The land use stratification system divides the county into five strata: cultivated dry, cultivated irrigated, urban, non-agriculture, and range. The delineation of these strata is made on conventional Agricultural Stabilization and Conservation Service panchromatic photography, generally at a scale of 1:20,000. Unfortunately, new photography is not available for every annual survey, and so the more outdated the photography is, the less meaningful the strata boundaries become. Because agricultural statistics are usually required for large geographical areas, some form of sampling is required in order to collect the data needed to produce reliable estimates within existing cost and time constraints. Stratifying an area into groups of homogeneous agricultural land use prior to the allocation of the samples improves not only the accuracy of the parameter being estimated, but also reduces the variance of that estimate. The only restriction upon such a stratification design is that both the boundaries and the areas of the strata are accurately located and determined. If this condition is not met, serious bias will result in the population estimates. As can be seen by comparing the Statistical Reporting Service strata, shown in Figure 2.3, with the stratified ERTS-1 image, it is possible to produce a much more detailed and up-to-date stratification using the ERTS-1 data than is possible using conventional techniques.

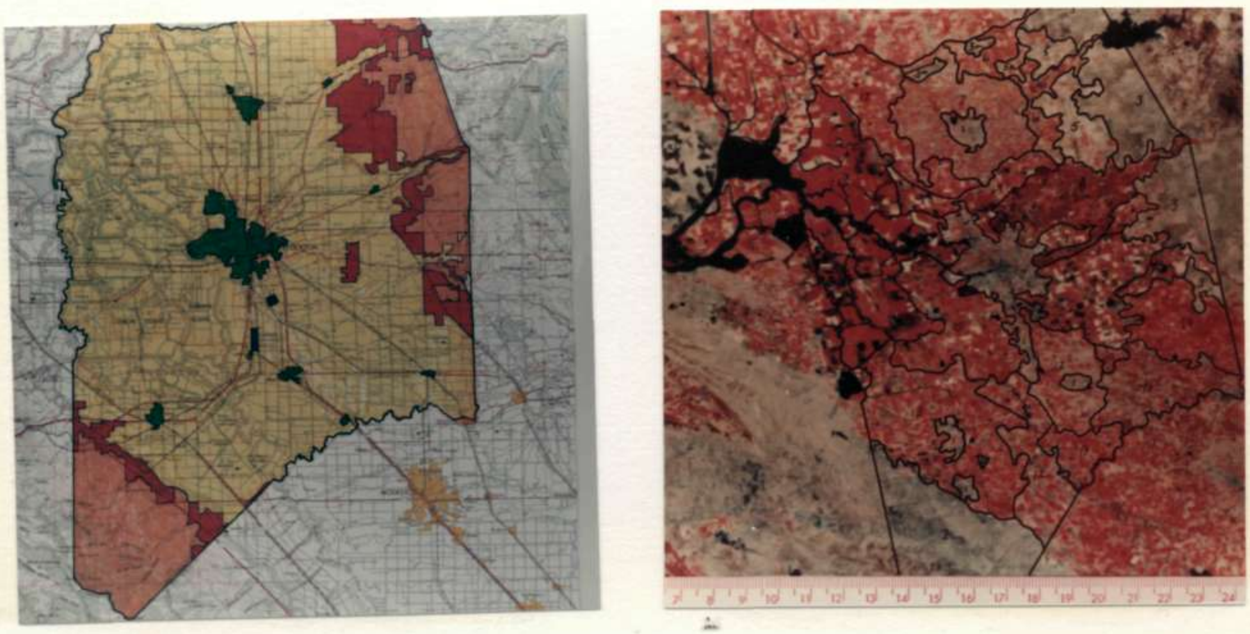

Figure 2.3 The illustration on the left shows San Joaquin County as stratified by the Statistical Reporting Service as a preliminary step in the allocation of crop inventory sample plots. On the right are stratifications as drawn on the ERTS-1 image of the same area.

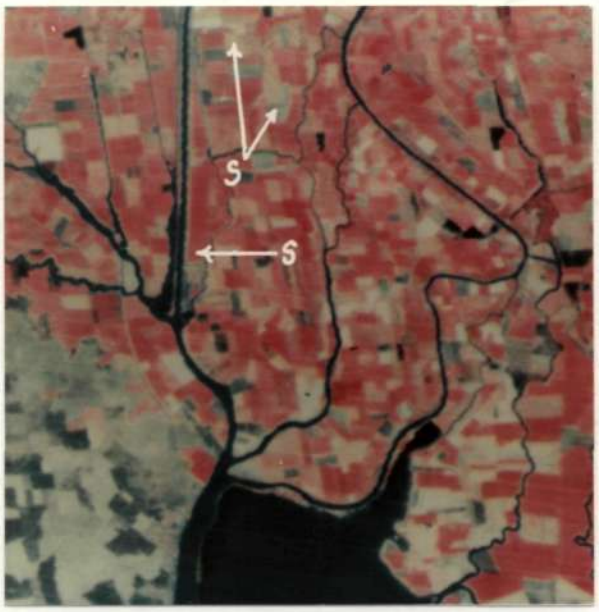

Figure 2.4 Three safflower fields as they appear on the ERTS-1 color composite in the test area are indicated by the arrows. The upper two fields have matured and appear a characteristic light brown, while the lower field is immature and appears red, allowing it to be easily confused with other field crops in the area. The scale of this photo is approximately 1:340,000, or 5.4 miles to the inch.

$$\% \text{ Correct} = \frac{\text{\# of fields correctly delineated as safflower}}{\text{total \# of safflower fields in the test area}} \times 100 = 79\%$$

$$\% \text{ Commission Error} = \frac{\text{\# of fields incorrectly delineated as safflower}}{\text{total \# of safflower fields in the test area}} \times 100 = 4.6\%$$

Considering the fact that in this initial test the interpreters were unable to exploit the advantage of sequential coverage which ERTS-1 will provide, and that perhaps more nearly "optimum" dates for crop discrimination can be found at other times of the year, these results were quite encouraging. Certainly they show that an interpreter can detect and delineate individual fields on the imagery. It was the general consensus of persons interpreting the ERTS-1 color composite that ground resolution for non-linear objects of medium contrast was on the order of 250 to 350 feet, and that it was possible to observe generally reliable signatures for fields down to 20 acres in size on the color composite.

b. Automatic Interpretation

Planned automatic data processing studies call for extracting agricultural information from both computer compatible tape and photographic transparencies using the Forestry Remote Sensing Laboratory computer system.

The processing of both types of data through CALSCAN* will give a comparison of classification results using an analog storage medium (film) versus digital storage (tape). The computer compatible tape of

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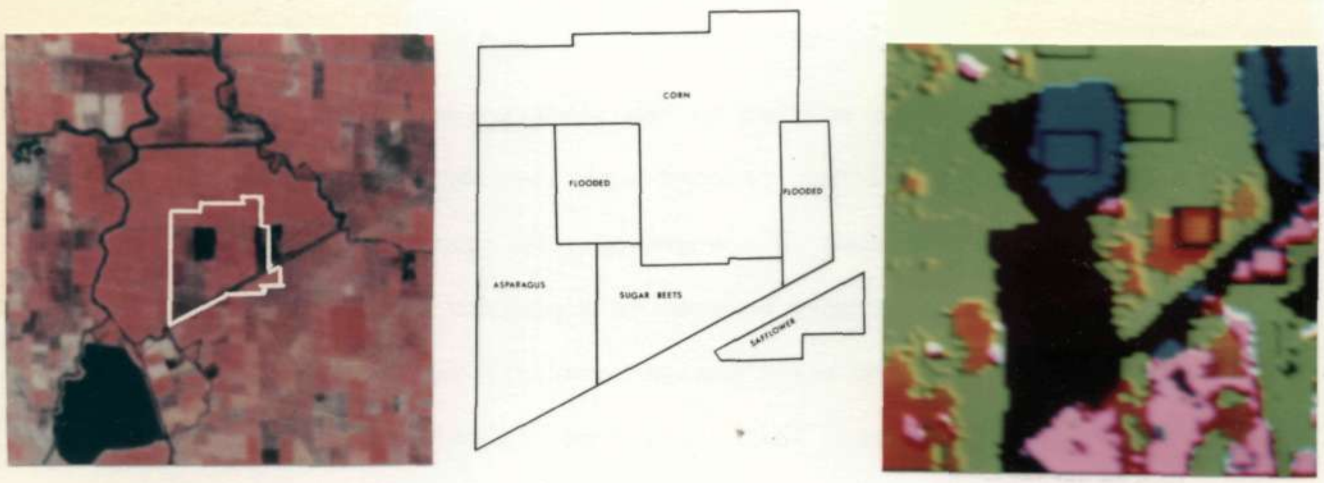
*CALSCAN is the Forestry Remote Sensing Laboratory version of the LARS-Purdue pattern recognition program, adapted to the CDC 6600/7600 system at the University of California, Berkeley.

the agricultural areas did not arrive in time to be analyzed. Therefore, the entire agricultural effort reported here was done using photographic transparencies acquired of the San Joaquin test site on July 25, 1972.

Of the forty-eight ground data cells in San Joaquin County, eleven cells in the field crop strata (as delineated by the photo interpreters in the stratification study described previously) were selected for intensive analysis.

Each cell was scanned on the transparency of the four MSS bands to a common scale and registration such that each data point represented a 250 x 250 foot spot on the ground. To accomplish this the map coordinates of the cells were entered in a program that computed the translation, rotation, and scale change necessary to place the map coordinates over the MSS images. This transformed coordinate information was then used by the scanner program to locate and scan the cells. Twenty-seven representative training areas were selected from the data to train the classification algorithm on the ten land use categories considered.

After the point-by-point classification was completed, each point was reclassified by an algorithm that considers the classification assigned to neighboring points. This technique improved the point-by-point classification between 10 and 30 percent depending on the homogeneity of the field. A field map of the ground truth was then laid over the final automatic classification results. Each field was then assigned to the class that had the maximum data point count within the field on the overlaid map (see Figure 2.5).



Enlarged ERTS-1 color composite

Ground truth map

Color display of computer classification

Figure 2.5 One 4-square-mile ground data cell in the San Joaquin County test site is illustrated here as seen on (1) an enlargement of a portion of an ERTS-1 color composite image, (2) a "ground truth" map, and (3) a color display on the Forestry Remote Sensing Laboratory TV monitor of a computer classification of crop types.

Table 2.3 summarizes the results of this classification, which resulted in an 84 percent overall correct identification. A total of 201 fields were classified in the test area. Again, these results are based on a field-by-field rather than a point-by-point identification, and are a result of an analysis of data from all four MSS bands. Use of the scanned photo data and pre-mapped field boundaries allowed classification down to a 20 acre field size. (The use of bulk-processsed MSS computer compatible tapes should allow classification to a 10 acre minimum field size when the smallest side is 600 feet.) The poor results in classification of some crop classes was attributed to the small field size in relation to the image resolution. However, considering that the available imagery was acquired on a single, non-optimum date, these results are surprisingly good, and would suggest that more carefully controlled inventories will yield even better results.

In the immediate future, data pertaining to the same cells that were analyzed using microdensitometer data will be extracted from the digital tapes for the same date and analyzed using the same training fields. The two data storage methods will then be compared to determine the relative accuracy and efficiency of the two storage media.

A computer program is now being implemented to allow the extraction from the digital tapes of irregularly shaped areas as delineated by a photo interpreter. This will reduce the total amount of data to be processed and allow the application of training data to delineated strata. This should increase accuracy and greatly reduce processing costs by decreasing the data processing necessary and minimizing the amount of

TABLE 2.3

RESULTS OF CALSCAN CLASSIFICATION OF
ERTS-1 DATA -- SAN JOAQUIN COUNTY, CALIFORNIA

		GROUND DATA										TOTAL	COMMISSION ERROR
		SUNF	ASPA	CORN	SORG	WATR	N.VEG	POTA	PLOW	SAFF	SUG.B		
CLASSIFICATION RESULTS	SUNF	4		1								5	20
	ASPA	4	96	5				3	4	4	5	115	17
	CORN	1	3	48				1				53	11
	SORG										1	1	100
	WATR		1			4						5	20
	N.VEG	1	1						1			3	100
	POTA							2				2	0
	PLOW		1					1	8			10	20
	SAFF.									5		5	0
	SUG.B.										2	2	0
TOTAL		10	102	51	0	4	0	7	13	9	5		
% CORRECT		40	94	94	–	100	–	29	62	56	40		

TOTAL PERCENT CORRECT 84.3

training data needed. The most time consuming phase of the data analysis is the correlation of ground truth data with the classification results. Another new program is nearly completed that will take field boundary information as delineated on high altitude photography, and overlay this information on the classification results, thus allowing automatic correlation of the two.

2.2 CONCLUSIONS

Certainly the studies and results discussed here are not a definitive demonstration of what can be done with ERTS-1 data in agriculture. Rather, an attempt has been made to illustrate what the <u>potential</u> of such data might be. The experiments were quite limited in scope, and the imagery available for analysis consisted of a single pass over the test site. Nevertheless, the results obtained were quite good, and certainly encouraging enough to generate enthusiasm for the extensive quantitative experiments which are planned for the coming growing season. It would appear that, with the repetitive coverage of ERTS, coupled with subsampling with conventional and high flight photography, techniques will be developed which will be of direct benefit to those agencies currently involved in the operational collection of agricultural resource information.

Indeed, much of the testing that will be carried out during the coming year will be geared directly to the data requirements of the cooperating state and federal agencies, to insure that rather than being merely an interesting academic exercise, this work will permit the potential of ERTS-1 data for providing genuine benefits to be defined and evaluated.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY

D ______

N ______

ID ______

DATE September 30, 1972

PRINCIPAL INVESTIGATOR R. N. Colwell

GSFC UN 640

ORGANIZATION University of California

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
	Agri-culture	Cropland	Delta	
100318175MB	✓	✓	✓	Rangeland
1003181754	✓	✓	✓	✓
1003181755	✓	✓	✓	✓
1003181756	✓	✓	✓	✓
1003181757	✓	✓	✓	✓
100318175MD	✓	✓	✓	✓

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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GSFC 37-2 (7/72)

Chapter 3

USE OF ERTS-1 DATA AS AN AID IN SOLVING WATER RESOURCE MANAGEMENT PROBLEMS IN CALIFORNIA (UN643)

Co-investigator: R. H. Burgy
Contributors: J. Malingreau, S. J. Houck
Dept. of Water Science and Engineering, Davis Campus

The "first look" interpretation presented herein is based on the initial imagery provided by NASA to this research team. This investigation is designed to test the operational feasibility of using ERTS-1 data to facilitate the solution of selected recurring water resource management problems in California. Based on ERTS-1 imagery covering test sites established in Central California, two of our three project objectives are reviewed:

1. Detection and qualitative assessment of gross water changes in developed deltaic and estuarine systems.

2. Acquisition of input data for optimum multiple-use management of large water resource systems.

Our third project objective, dealing with snowpack delineationg and prediction of yields, is necessarily omitted from this report since the new imagery was acquired during the snow-free summer season.

The first assessment has been completely qualitative. The potential sites selected for ground study are evaluated on the basis of the imagery provided by ERTS-1. A list of parameters related to water resources and hydrologic uses is given preliminary appraisal with respect to the capability indicated for ERTS-1 imagery characteristics.

This report has utilized the following frames of ERTS-1 imagery:

ERTS-E - 1002-18131-4	ERTS-E - 1002-18134-4
ERTS-E - 1002-18131-5	ERTS-E - 1002-18134-5
ERTS-E - 1002-18131-6	ERTS-E - 1002-18134-6
ERTS-E - 1002-18131-7	ERTS-E - 1002-18134-7

ERTS-E - 1003-18175-457

The ERTS-1 images can be benficially used at two levels of hydrologic analysis. Firstly, they allow the mapping of open water bodies (such as lakes, ponds, reservoirs, deltas, and estuaries) and delineation of the hydrologic network.

Secondly, they provide an additional tool for use in the analysis of some parameters of aquatic systems and their surrounding watersheds, thereby producing input data for the optimum multiple-use management of large ecosystems.

Concerning mapping of water resources, the main value of ERTS-1 imagery is that it provides for the first time a synoptic coverage of the entire area of study in different wavelengths with good ground resolution sufficient to map most of the water features. Surface water bodies and water courses are clearly delineated in the MSS bands 6 and 7 and in the simulated infrared ektachrome color composite. When the image contrast between water and the surrounding land is great, the smallest resolvable water element is probably no more than 100-200 feet across. Although the interest of mapping water bodies in the state of California may appear to be small because of the extensive availability of hydrological data through classical channels, satellite images are

C

being well received. Because of the availability of ground truth concerning that subsystem of the hydrologic cycle, the images obtained over study sties may be used to test the accuracy that could obtained in a world-scale survey of continental surface-water resources. Further, the images will be used for monitoring seasonal variations in surface detention storage and ephemeral streams, both of which are parameters generally neglected because of the cost of data acquisition or the inaccessibility of the sites. Eventually we also will attempt snowpack monitoring and water yield prediction using ERTS-1 sequential imagery.

Within the general region identified as the San Francisco Bay and Sacramento-San Joaquin River Delta, several study areas have been selected. These may be classified into groups which relate directly to the "Hydrologic System Conceptual Model" which we have developed in connection with our ongoing research under the UC-NASA Grant Project NGL-05-003-404 reported in May, 1972, via the Annual Report, "An Integrated Study of Earth Resources in the State of California using Remote Sensing".

This "Hydrologic Model" includes subsystems and parameter descriptions applicable to the analysis of imagery from ERTS-1. The "Stream and Estuaries Subsystem" and the "Reservoir and Lakes Subsystem" parameters are used for assessment of the aquatic components. The terrestrial components have been grouped under the four general headings,

1. Watershed Delineation
2. Watershed Topography

3. Vegetation; Type and Coverage

4. Land Use

A listing of the selected study areas is presented below and the sites are identified in Figure 3.1. These locations were picked to provide a broad array of conditions which are typical of aquatic systems and representative of the specific region under consideration. Accessibility for "ground truth" data acquisition together with good background information and a suitable data base are inherent attributes of the selected sites.

Selected Study Areas

Sacramento - San Joaquin River Delta Region, California

1. Lindsey Slough
2. Sacramento River near Rio Vista
3. Andrus Island (Brannan Island)
4. Beaver Slough
5. Hog Slough
6. Sycamore Slough
7. Frank's Tract

Other Sites

8. Colusa Basin Drain into Sacramento River
9. Discovery Park (Confluence of American & Sacramento Rivers at Sacramento)
10. Suisun Bay
11. San Pablo Bay (Salt concentration ponds)
12. Lake Berryessa

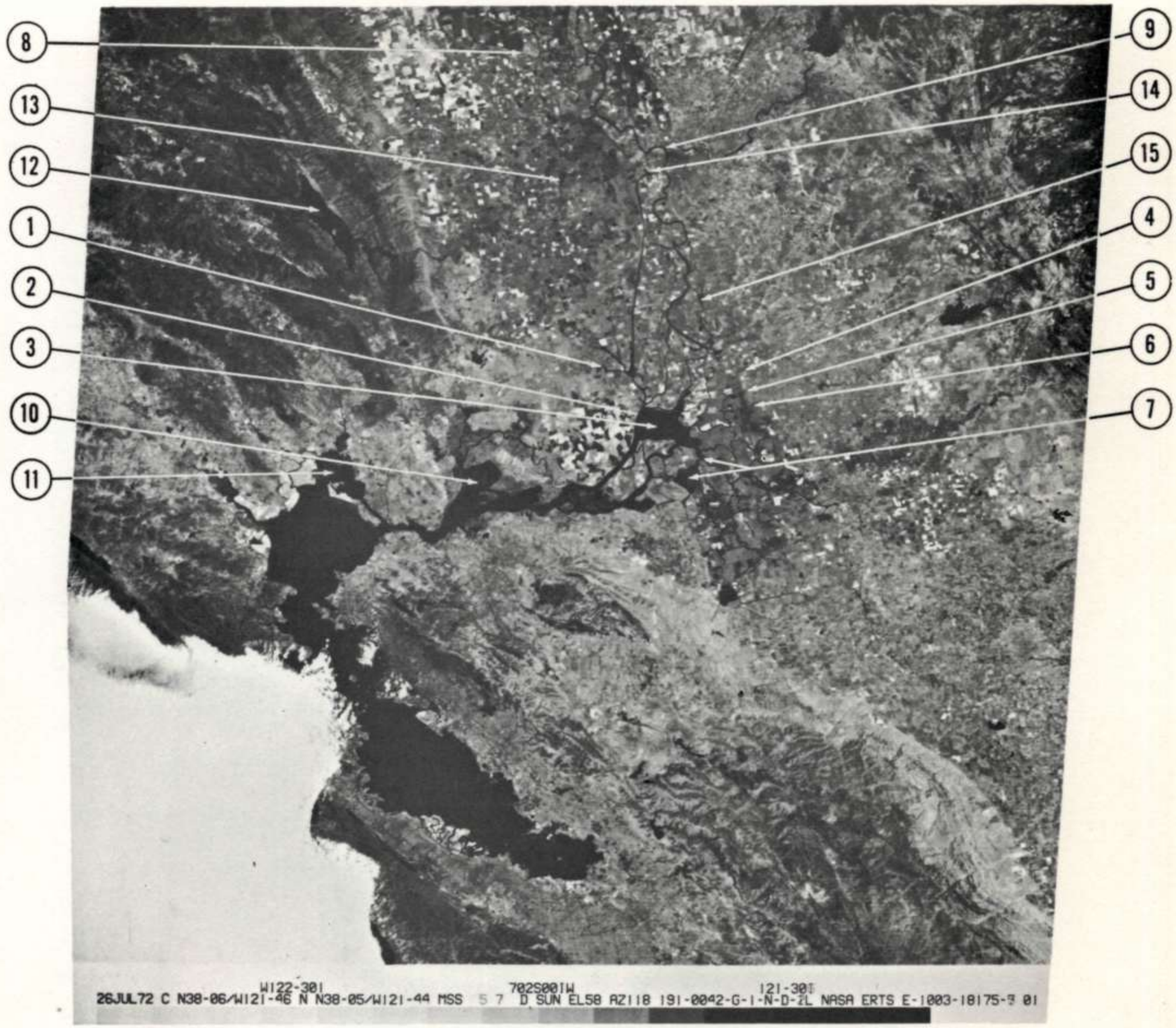


Figure 3.1 Selected study areas in San Francisco Bay and Sacramento-San Joaquin River Delta test sites.

13. Davis - Municipal Sewage Stabilization Ponds

14. Lake Washington, (Port of Sacramento)

15. Stone Lake

Table 3.1, An Evaluation of the Selected Study Areas, is marked to indicate the principal water-related parameters considered useful for a comprehensive hydrological analysis at the site.

Table 3.2 presents a listing of the available multistage-multispectral imagery covering the several sites. The judgment value of the utility of the various images available is based on the actual possibility of recognition of a test site and on the amount of details discernible in the sites. This was an intermediate step in the procedure toward defining test site capabilities for ongoing ERTS-1 interpretation, to be supported by ground truth exercises.

Within the limits of coverage of ERTS-1 imagery currently forwarded to this project, together with the resolution characteristics of this imagery, certain of the initial site selections may be discarded or replaced. Contingent upon receipt of the missing ERTS-1 products, the final appraisal of the sites will be completed rapidly. For example, as of the time when it was necessary for us to complete this first progress report, only a color composite image (ERTS 4, 5, 7) was available for our test site. Lacking the separate bands 4, 5, 6 and 7, we were not able to fully evaluate several of our designated sub-sites (study areas) with respect to important water-related parameters.

Table 3.3 presents the initial evaluation of the several image forms in relation to the water-related parameters listed previously in

TABLE 3.1 EVALUATION OF SELECTED STUDY AREAS

HYDROLOGIC PARAMETERS	SELECTED STUDY AREAS												
	Lindsey Slough 1	Sacto. R.-Rio Vista 2	Andrus Is. 3	Beaver, Hog Sycamore S. 4,5,6	Frank's Tract 7	Colusa Basin Drain 8	Discovery Park 9	Suisun Bay 10	S.P. Bay Ponds 11	Lake Berryessa 12	Davis Ponds 13	Lake Washington 14	Stone Lake 15
Stream Morphology	X			X		X	X	X					
Surface Velocity & Direction		X		X	X		X	X					
Stream Stage-Discharge	⊗	X		X		X	X						
Turbidity-Suspended Sediment	⊗	⊗	X	X	X	X	X	⊗	X	⊗	X	X	X
Hydrocarbon Surface Films		X	X		X		X	X					
Water Chemistry	⊗	X	X	X	X	X	⊗	X	⊗		X		
Surface Temperature	X	X	X	X	X	X	X	X	X	X	X	X	
Surface Disolved Oxygen	X	X	X	X	⊗	X	X	X		X	X	X	
Phytoplankton Density	X	X	X	X	⊗	X	X	⊗	X	⊗	⊗	X	⊗
Riparian Vegetation	X	X		⊗	X	X	X	X	X	X	X		
Lake Surface Area					X					X			X
Lake Depth					X					X	X	X	X
Change in Storage			⊗							⊗			X
Watershed Delineation	X			X		⊗				X			X
Watershed Topography	X			X		X				X			X
Vegetation-Type & Coverage	X		X	X		X	X	X		X			X
Land Use	X	X	⊗	X	X	X	X	X	X	X		X	X

⊗ Important parameter at selected study area
X Additional parameter at selected study area

TABLE 3.2 REMOTE SENSING IMAGERY USEFULNESS AT SELECTED STUDY AREAS

REMOTE SENSING IMAGERY	SELECTED STUDY AREAS												
	Lindsey Slough 1	Sacto. R. - Rio Vista 2	Andrus Is. 3	Beaver, Hog, Sycamore S. 4,5,6	Frank's Tract 7	Colusa Basin Drain 8	Discovery Park 9	Suisun Bay 10	S.P. Bay Ponds 11	Lake Berryessa 12	Davis Ponds 13	Lake Washington 14	Stone Lake 15
ERTS (4) GREEN	NCA	2	2	4	3	NC	3	NCA	NCA	NCA	NCA	4	4
ERTS (5) RED	NCA	2	1	4	3	NC	2	NCA	NCA	NCA	NCA	4	3
ERTS (6) NEAR IR	NCA	2	1	4	2	NC	2	NCA	NCA	NCA	NCA	3	3
ERTS (7)'FAR'IR	NCA	2	1	2	2	NC	2	NCA	NCA	NCA	NCA	3	2
ERTS (4, 5, 7) MSS COMPOSITE	2	1	2	2	2	1	2	1	1	2	3	2	2
U2 (1) GREEN	2	2	NCA	1	2	1	1	2	2	2	1	1	1
U2 (2) RED	1	1	NCA	2	1	1	2	1	2	2	2	2	2
U2 (3) IR	2	1	NCA	1	1	2	2	3	1	2	1	1	1
U2 (4) CIR	1	1	NCA	1	1	1	1	1	1	1	1	1	1
RB 57 CIR	1	1	NCA	NCA	1	NCA	NCA	1	1	NCA	NCA	NCA	NCA

1 - VERY USEFUL
2 - USEFUL
3 - MAY BE USEFUL
4 - NOT USEFUL
NCA - NO COVERAGE AVAILABLE

TABLE 3.3 REMOTE SENSING IMAGERY USEFULNESS FOR EVALUATING PARAMETERS

HYDROLOGIC PARAMETERS	ERTS-1 MSS					U2				RB57
	GREEN 4	RED 5	NEAR IR 6	FAR IR 7	COMPOSITE 4,5,7	GREEN 1	RED 2	IR 3	CIR 4	CIR
Stream Morphology	3	3	1	1	1	2	1	1	1	1
Surface Velocity & Direction	4	4	4	4	4	3	3	4	4	3
Stream Stage-Discharge	4	4	3	3	3	4	4	3	3	3
Turbidity-Suspended Sediment	2	3	4	4	2	2	1	3	1	1
Hydrocarbon Surface Films	*	*	*	*	*	*	*	*	*	*
Water Chemistry	*	*	*	*	*	*	*	*	*	*
Surface Temperature	4	4	4	4	4	4	4	4	4	4
Surface Disolved Oxygen	4	4	4	4	4	4	4	4	4	4
Phytoplankton Density	2*	3*	4*	4*	2*	2*	3*	4*	2*	2*
Riparian Vegetation	4	*	*	*	*	2	2	4	1	1
Lake Surface Area	4	2	2	1	1	3	2	1	1	1
Lake Depth	3*	4	4	4	4	3*	4	4	4	4
Change in Storage	4	3	2*	2*	2*	4	3	2*	2*	2*
Watershed Delineation	3	3	4	3	2	3	2	2	1	1
Watershed Topography	3	2	3	2	2	3	2	2	1	1
Vegetation-Type & Coverage	2*	1*	4	4	1*	2*	1*	2*	1*	1*
Land Use	3	2*	4	4	1*	3	1*	2*	1*	1*

1 - VERY USEFUL   3 - MAY BE USEFUL   * - NEED GROUND TRUTH

2 - USEFUL   4 - NOT USEFUL

Table 3.1. Three elements used in this evaluation (Table 3.3) include:

1. The interpreter's ability to recognize the test areas and to judge the relative amount of information contained in the images by visual inspection.

2. Comparisons of satellite imagery with high and low flight imagery in a multi-stage analysis, (U2 flights and RB57 missions).

3. Knowledge of theoretical target-radiation relationships mentioned in the literature and supplemented by previous experience on some actual case studies.

The numerical ratings placed in Table 3.3 are the integrated values summarizing the above points. The objectivity of the results shown in Table 3.3 will be further tested as sequential imagery and ground truth are acquired.

Multispectral Scanner Bands used on ERTS-1 give the following summarized results with respect to water-related parameters:

- The water penetrating capabilities of the green band (MSS 4) make it most useful for studying intrinsic characteristics of water bodies.

- The red band (MSS 5) allows a better estimation of watershed conditions with respect to vegetation cover and land use.

- The infrared bands (MSS 6, 7) are most useful for detecting and delineating the water bodies and drainage networks. There does not seem to be a visual difference between the two bands but densitometric analyses may yield additional information.

- The color composite image (MSS 4, 5 and 7) centering on the

Delta area provides the most information both on parameters of the water bodies themselves and on the surrounding terrestrial system. The combination of the three bands enhances the evaluation of sediment patterns, riparian and marshy vegetation, watershed vegetation cover and land use.

To this point no enhancement techniques were actually used and no measurements were performed on the images. All estimations given in the tables are qualitative. Obviously, more refined quantitative values will be assignable to some of the factors with sequential coverage sustained by simultaneous ground truth.

Quantifying data for hydrologic parameters measured by satellite remote sensing will be mainly dependent upon:

- the possibilities of measuring reflectance values on the images (or on raw data)

- the possibility of relating these values to ground truth samples (and/or lower elevation imagery) taken at the time of coverage.

On the basis of a preliminary evaluation of ERTS-1 images over the Delta test site, quantitative data are expected to be obtainable for the following hydrologically related parameters:

- watershed area and topography
- vegetation type and coverage
- land use
- surface water area and changes in storage
- stream morphology
- turbidity and suspended sediments
- phytoplankton density
- changes in riparian and marshy vegetation

Sequential coverage of the test areas is expected to greatly improve the hydrologic analysis in that:

- it will allow the analysis of time dependent factors (most hydrologic parameters are time dependent)
- it will aid in discriminating between factors on the basis of their differential rates of spectral variation.

Temporal variations of the following factors are expected to be measurable by sequential coverage, both in the short term and over longer periods:

- Phytoplankton density (appearance of blooms, indicator of pollution, eutrophication).
- Water quality and consequent influences on riparian and aquatic vegetation, and on the spectral reflectance characteristics of water.
- Turbidity and suspended sediments.
- Water regime and storage.
- Watershed conditions which influence the hydrologic cycle such as:
    - vegetation cover
    - land use

2.1 PRELIMINARY CONCLUSIONS:

- ERTS-1 imagery provides a highly useful synoptic view of the hydrologic characteristics of a region.
- ERTS-1 imagery provides sufficiently high spatial resolution to readily define regional and individual watershed drainage networks,

greatly exceeding the image detail anticipated prior to launch.

- ERTS-1 imagery is directly capable of indicating those gross water resource characteristics noted in the text.

- ERTS-1 imagery provides direct guidance for sampling and control for monitoring water quality phenomena.

Chapter 4

ERTS-1 DATA AS AN AID TO RESOURCE MANAGEMENT IN NORTHERN CALIFORNIA (UN257)

Co-investigator: Gene A. Thorley
Contributors: Paul Krumpe, Ronald Lauer, Jim Nichols, Sheri Wolf
Forestry Remote Sensing Laboratory, Berkeley Campus

Two major wildland studies are being carried out in northern California by the Forestry Remote Sensing Laboratory, namely:

1. Determination and analysis of wildland resource parameters through the use of ERTS-1 and aircraft data in the Feather River headwaters area;

2. Analysis of the California northern coastal zone environment with the aid of ERTS-1 and aircraft data.

Within the spearate sections that follow, preliminary research results are presented. However, most of the work completed to date, and reported upon herein, has been performed within the Feather River test site.

Table 4.1 lists the user agency groups which are keenly interested in the results of this research.

4.1 REGIONAL ANALYSES

4.1.1 Approach

Our approach to wildland vegetation/terrain resource evaluation on both ERTS-1 and high altitude color infrared imagery in the

TABLE 4.1 USER AGENCY COOPERATION
WILDLANDS RESEARCH APPLICATIONS PROJECTS

USER GROUP AGENCY	PERSONNEL CONTACTS	REMOTE SENSING RESEARCH APPLICATION
CALIFORNIA REGION FRAMEWORK STUDY COMMISSION FOR SOUTHWEST INTER-AGENCY COMMITTEE: WATER RESOURCES COUNCIL	MR. JIM COOK (USFS) MR. LYLE KLUBBEN (USFS) MR. WILLIAM FRANK	REGIONAL VEGETATION/TERRAIN MAPPING LAND USE PRACTICES AND CHANGES LANDSLIDE AND STREAM SEDIMENTATION DETECTION
REDWOODS NATIONAL PARK, U.S. NATIONAL PARK SERVICE	MR. H. T. HATZIMANOLIS RESOURCES MANAGEMENT SPECIALIST	CHANGE DETECTION ANALYSIS LAND USE PATTERNS ON ADJACENT LANDS VEGETATION INVENTORY REGENERATION ANALYSIS
DEPARTMENT OF WATER RESOURCES, STATE OF CALIFORNIA	MR. G. SAWYER MR. A. DE RUTTE	SNOWPACK DETECTION HYDROLOGIC OUTPUT PREDICTIONS
CALIFORNIA COOPERATIVE SNOW SURVEY	MR. V. LEMMONS	SNOWPACK DETECTION AND HYDROLOGIC PREDICTIONS
CALIFORNIA DEPARTMENT OF CONSERVATION DIVISION OF FORESTRY	MR. T. ARVOLA MR. C. PHILLIPS	VEGETATION-SOILS INVENTORY FIRE DAMAGE APPRAISAL RANGELAND CONTROL BURNING MONITORING COMPLIANCE WITH FOREST PRACTICE ACT
U.S. FOREST SERVICE	MR. JIM MC LAUGHLIN	SOILS-TERRAIN ANALYSES
TAHOE REGIONAL PLANNING AGENCY	MR. JIM BRUNER	ENVIRONMENTAL CHANGE DETECTION SEDIMENT POLLUTION ANALYSIS LAND USE INVENTORY
CALIFORNIA STATE DEPARTMENT OF PARKS AND RECREATION	MR. GEORGE RACKELMANN MR. JOHN HAYNES MR. SANDY RABINOWITCH MR. KEN COLLIER MR. ED POPE	LANSCAPE INVENTORY SITE LOCATION AND PLANNING

2.5 million acre Feather River Watershed Region (see Figure 4.1) emphasizes the following objectives: (1) the development and evaluation of multistage interpretation and mapping techniques to analyze extensive distributional vegetation and terrain entities, (2) the quantitiative testing of manual and automatic image interpretation procedures and results in the detection, delineation and classification of landscape elements, (3) the development of interpretation aids and related resources descriptors, and (4) the determination of cost/time and benefit/effectiveness ratios of mapping resources within extensive, ecologically diverse wildland areas. The initial approach to this extensive wildland resource investigation has concentrated on acquiring, compiling, and verifying ground control data. These data have been obtained using contact landscape sampling, low oblique 35 mm photos taken from low flying aircraft, existing resource map data, and ground-controlled high altitude imagery.

With the aid of a classification scheme (see Figure 4.2) which has been described based on ecological criteria and RB57 (scale 1:120,000) false-color infrared 9 x 9 inch transparencies, a ground controlled vegetation/terrain resource map has been prepared (see Figure 4.3). In addition, as illustrated in Figure 4.4, regional ground controlled maps have been prepared for lithologic geology, mean annual precipitation, soil series complexes, elevational zones, and drainage network. These control maps, as well as an existing vegetation cover type map which is shown in Figure 4.5, provide the necessary base information for which results derived from ERTS-1 can be compared.

D

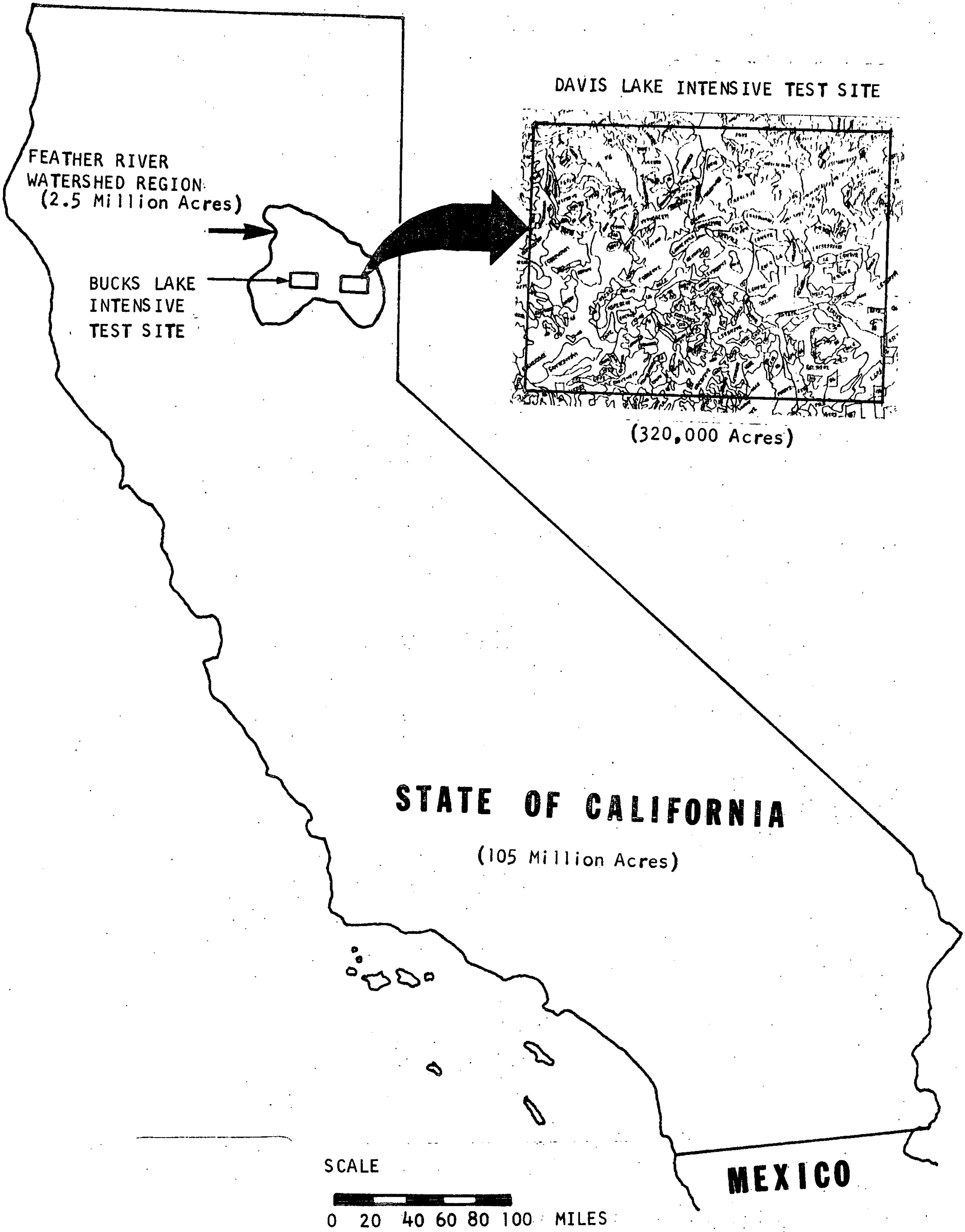


Figure 4.1 Wildland vegetation-terrain mapping is being conducted, using ERTS-1 imagery, within the Feather River watershed region. The vegetation type map in the upper right was made for the Davis Lake study area using high flight false-color infrared photography.

Figure 4.2 CLASSIFICATION SCHEME OF VEGETATION-TERRAIN RESOURCES OF THE FEATHER RIVER WATERSHED REGION

FOREST RESOURCES

Coniferous Forests

- A. High Elevation Red Fir Forest
- B. Westside Intermediate Mountain Conifer
- BB. Eastside Intermediate Mountain Mixed Conifer
- C. Eastside Intermediate Pine-Scrub Forest
- D. Eastside Northern Juniper Woodland
- E. Eastside Timberland-Chaparral Complex

Hardwood Forests

- F. Intermediate Mountain Xeric Hardwoods
- G. Westside Foothill Pine-Oak Woodland
- GG. Westside Foothill Oak Woodland-Grass
- GC. Westside Foothill Oak Woodland-Chaparral
- GGC. Westside Foothill Oak Woodland-Grass-Chaparral
- H. Mixed Mesic Hardwood Communities
- I. Westside Foothill Mixed Hardwood-Conifer Forest

NON-FOREST RESOURCES

Chaparral

- J. Westside Valley Front Foothill Chaparral
- K. Westside Intermediate Mountain Chaparral
- KK. Eastside Intermediate Mountain Chaparral
- L. Eastside Valley and Basin Front Sagebrush Scrub

Grassland-Meadow-Marshland Complex

- M. Subalpine Grassland
- N. Intermediate Interior Valley Xeric Grassland
- O. Mesic Meadow Complex
- P. Freshwater Marshland

AGRICULTURAL AND RANGELAND RESOURCES

- Q. Mesic Cultivated Croplands
- R. Mesic Rangeland
- S. Xeric Eastside Grassland-Scrub Rangeland

OTHER LANDSCAPE FEATURES

- T. Forest Plantation Sites
- U. Urban-Residential-Commercial Sites
- V. Exposed Soil
- W. Exposed Bedrock
  - WB. Basalt
  - WA. Andesite
  - WR. Rhyolite
  - WP. Pyroclastics
  - WG. Granite
  - WU. Ultrabasics
  - WS. Sedimentary
  - WM. Metavolcanics

HYDROLOGIC RESOURCES

- X. Standing Water
- Y. Running Water
- Z. Snowpack

VEGETATION-TERRAIN RESOURCES PERCENT COMPOSITION RANGE WITHIN HOMOGENEOUS DELINEATED AREAS

PERCENT COMPOSITION	CODE NUMBER
0 - 5	1
6 - 20	2
21 - 40	3
41 - 60	4
61 - 80	5
81 - 100	6

Figure 4.3 Vegetation/terrain homogeneous area delineation within the Feather River Watershed Region (2.5 Million Acres). This map was prepared from a mosaic of approximately sixty transparency overlays (imagery scale 1:120,000) on which delineations were made. Classification of these areas is in progress using the scheme presented in Figure 4.2. The completed regional map will provide the necessary real-time ground controlled vegetation/terrain data essential to regional analyses of ERTS-1 imagery.

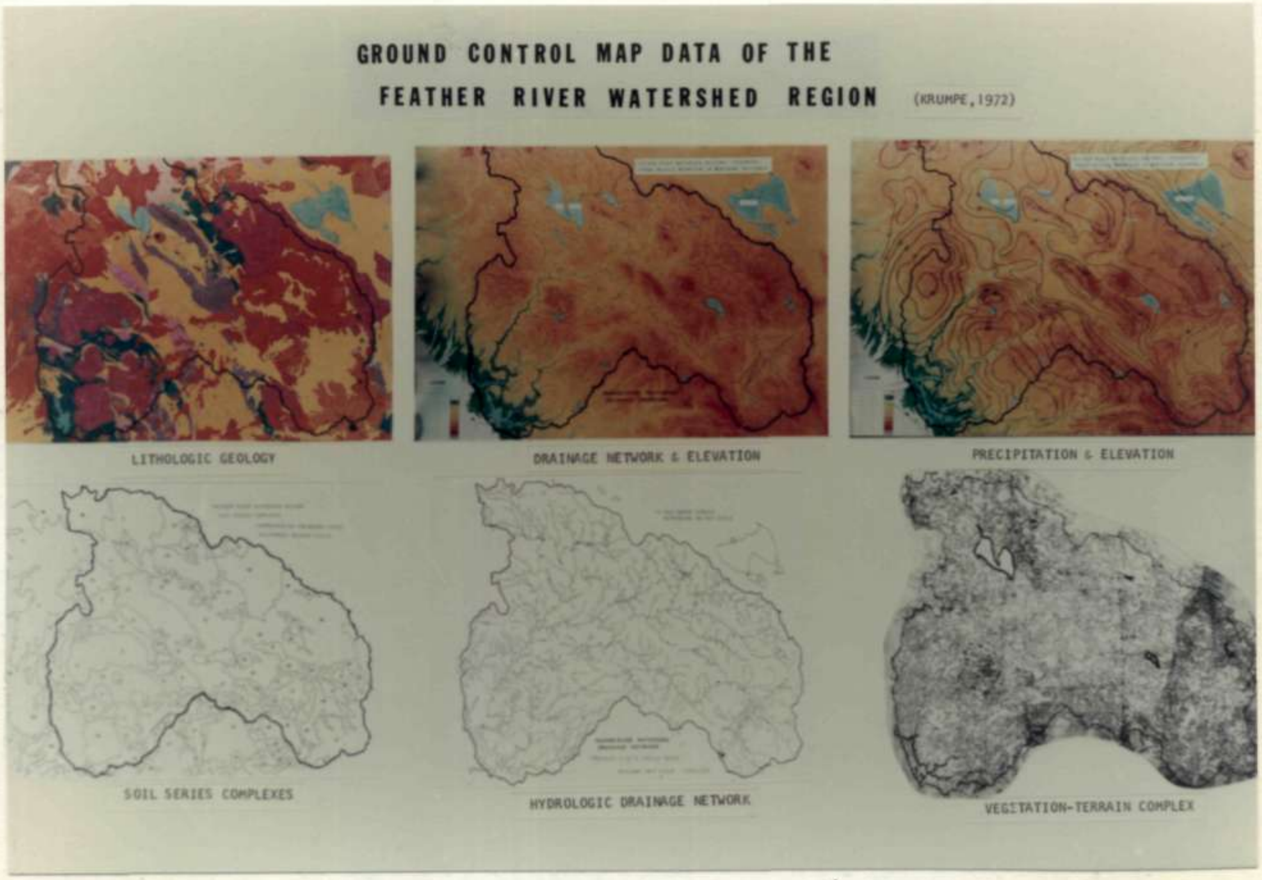


Figure 4.4 Feather River watershed regional ground control data maps have been compiled and prepared to provide the necessary baseline information to which ERTS-1 imagery interpretation results can be compared. The original scale of these maps is 1:250,000. The lithologic geology map is a color coded modified rendition of the Chico and Westwood, California geologic map sheets (Olaf P. Jenkins edition). The drainage network & elevation map was prepared from 1:250,000 USGS topographic maps, using a color code to depict 1000 foot elevation zones. The mean annual precipitation map (overlaid on elevational zones) was prepared from an original map produced by the meteorologic unit of the California Department of Water Resources in 1959. The modified soil series complexes map originated from the Comprehensive Framework Study: California Region (1971). The map of the Feather River regional hydrologic drainage network is based on the Strahler (1957) stream order system, and provides the basis for characterizing drainage basin parameters. The map showing the vegetation/terrain complex homogeneous area delineations is described in detail in Figure 4.3.

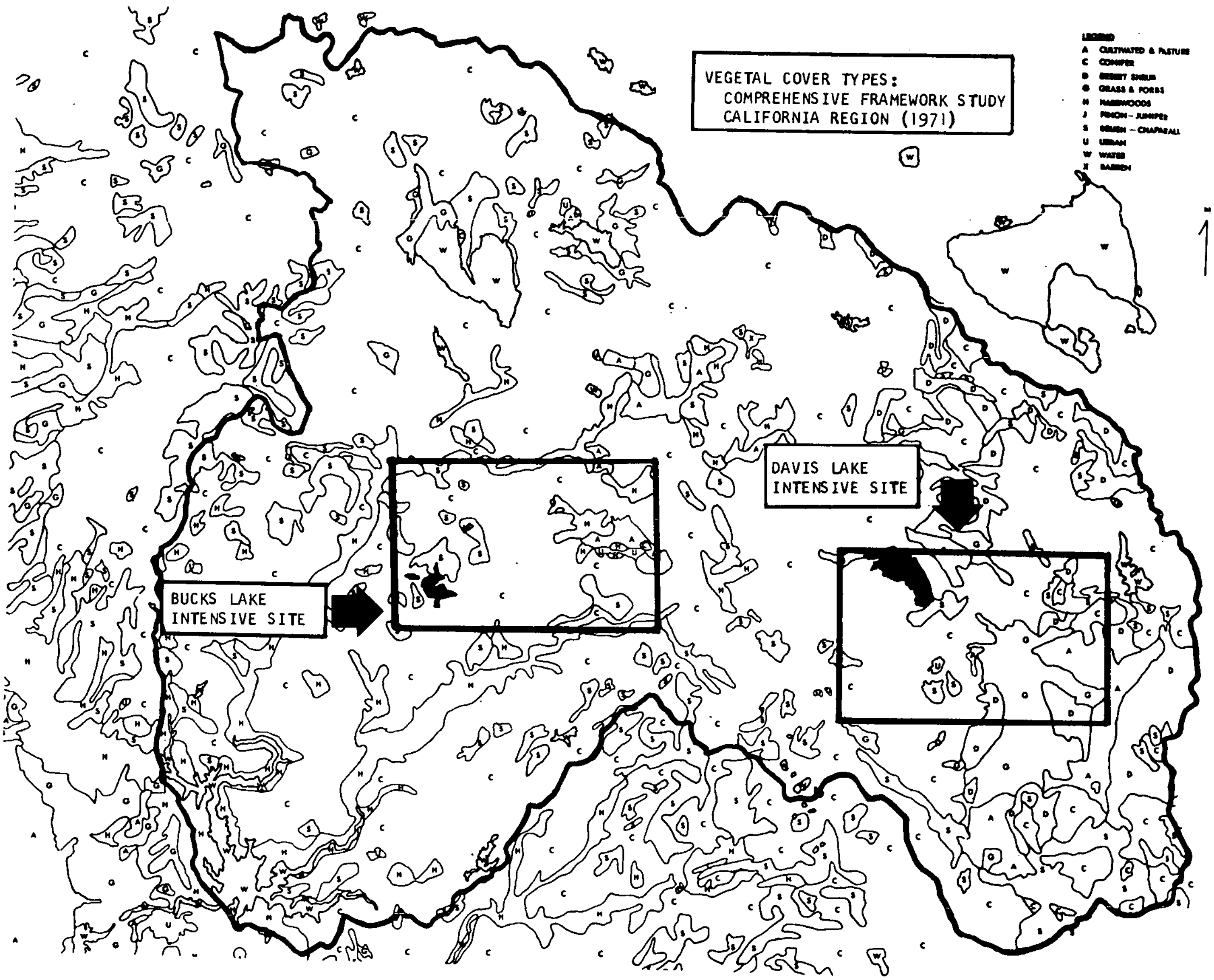


Figure 4.5 This map of vegetal cover types within the Feather River watershed region, compiled and produced by the Comprehensive Framework Study: California Region (1971), is a portion of a larger map of the Sacramento Basin Subregion. The map represents state-of-the-art regional mapping capability and was prepared from referenced materials dating from 30 years ago to more recently. The mapped resources are highly generalized and lack a real-time information documentation capability. The two intensive study areas presented under investigation on ERTS-1 imagery are delineated on this figure. Note the extremely generalized mapped information in the Davis Lake intensive study area compared with the ground controlled resource data in Figures 4.7b and 4.8, part 4 prepared from high altitude imagery interpretation analyses.

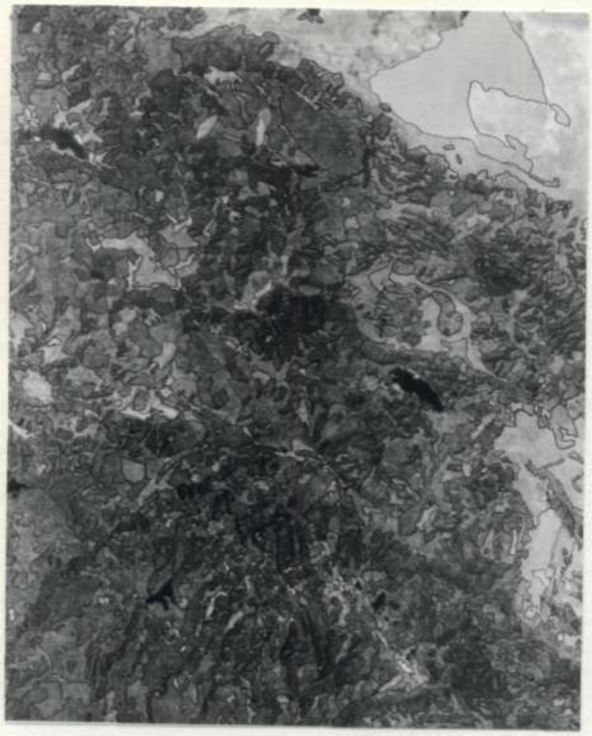
It is important to note that the map shown in Figure 4.5, produced by the Comprehensive Framework Study -- California Region, 1971, is a portion of a larger map of the Sacramento Basin Subregion, and represents "state-of-the-art" regional mapping prepared from the referenced materials dating from 30 years ago to more recently. The map is vastly generalized and of questionable validity when compared with ground observations. It by no means equates with the "real-time" mapping capability that is obtainable using either the high altitude CIR interpretations shown in Figure 4.3, or the ERTS-1 multiband, multidate interpretations.

4.1.2 Results and Discussion

Since the RBV system currently is inoperable, emphasis has been placed during the regional analyses on evaluating the ERTS-1 Multispectral Scanner System (MSS) imagery.

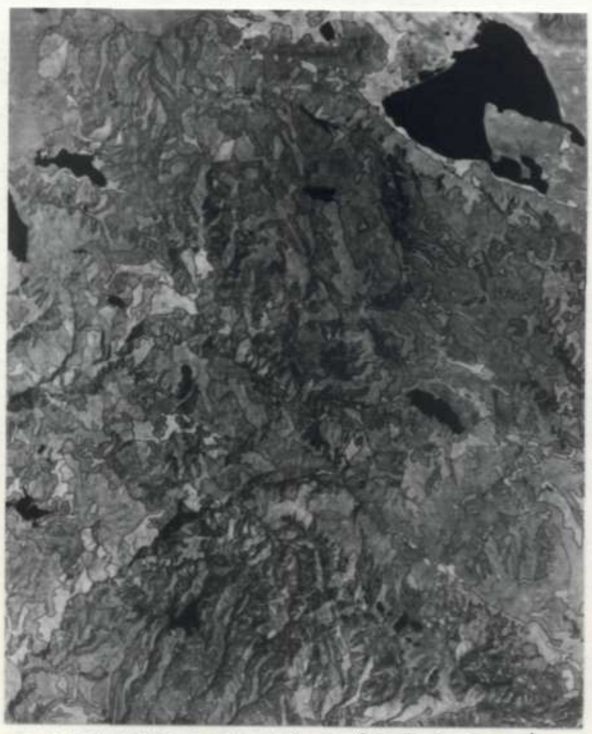
The following MSS single band images have been investigated with respect to information content about wildland resources: No. 4, green (.5-.6mμ); No. 5, red (.6-.7 mμ); No. 7, infrared (.9-1.1 mμ) and the false-color combined MSS 4-5-7 image. Original 1:1,000,000 NASA-Goddard single band, black-and-white transparency images were professionally enlarged to a 16 x 20 inch print format, approximating the ground control map scale of 1:250,000. The false-color combined MSS image used in this preliminary evaluation was a third-generation copy enlargement (16 x 16 inch) derived from an initially available MSS (9 x 9 inch) color print of the region. Continuous tone homogeneously determined areas were delineated on overlays of these four enlarged images (see Figure 4.6) by trained photo interpreters. Evaluations of these delineations on each MSS single band and on the color-combined image, were accomplished by direct visual comparison with analogous areas on compiled ground control maps showing lithology, drainage, elevation, and precipitation (see Figure 4.4). Image evaluation centered on the ability of the analyst to both <u>detect</u> and <u>identify</u> resources as they generally appeared within analogous homogeneous areas. These comparisons between and among images and ground-control maps, formulate the basis for preparation of a feasibility diagram (see Table 4.2) assessing the interpretability of wildland resources seen on ERTS-1 imagery.

Preliminary results demonstrating the feasibility of wildland resource object detection and identification on the ERTS-1 imagery generally indicate interpreter ability to <u>detect</u> resources and analogous cover-type indicators; however, object <u>identification</u> appears more difficult. The results shown in Table 4.2 indicate that the MSS green band No. 4 (Figure 4.6) appears most useful for purposes of Eastside Valley and Basin Front Sagebrush-Scrub identification, as well as for main highways and logging road identifications, where detectable. The MSS red band No. 5 has been assessed as useful for identifying High Elevation Red Fir Forest, Intermediate Interior Valley Xeric Grassland, Mesic Cultivated Croplands, Mesic Rangeland, Xeric Eastside Grassland-Scrub Rangeland, sedimentary bedrock, standing water, and highways and logging roads. Perhaps the least useful single band image with respect to object identification is the infrared band No. 7, where only Mesic



GREEN BAND NO.4 (0.5-0.6 mμ)

RED BAND NO.5 (0.6-0.7 mμ)



INFRARED BAND NO.7 (0.8-1.1 mμ)

COLOR ENHANCED COMBINED BANDS NOS. 4-5-7 (0.5-1.1 mμ)

Figure 4.6 Vegetation/terrain resources of the Feather River watershed region (2.5 Million Acres) as determined by macro-delineations of tone differentiation on MSS bands Nos. 4,5,7, and false color enhanced image of bands Nos. 4-5-7 combined. Analyses of line delineations provide the basis for preparation of the feasibility diagram, Table 4.2.

Table 4.2 PRELIMINARY INDICATORS OF THE FEASIBILITY OF WILDLAND LANDSCAPE FEATURE DETECTION AND IDENTIFICATION WITHIN THE FEATHER RIVER WATERSHED REGION ON HIGH ALTITUDE AND ERTS-1 IMAGERY

LEGEND

- ● ● ● EASILY DETECTABLE
- ● ● MARGINALLY DETECTABLE
- ● NOT DETECTABLE
- ● ● ● EASILY IDENTIFIABLE
- ● ● MARGINALLY IDENTIFIABLE
- ● NOT IDENTIFIABLE

IMAGERY PARAMETERS										
VEHICLE	HIGH ALT. RB57		ERTS-1		ERTS-1		ERTS-1		ERTS-1	
SENSOR SYSTEM	RC-8 CAMERA		MSS BAND #4		MSS BAND #5		MSS BAND #7		MSS BANDS 457	
MISSION # & DATE [a]	MX 139(7-25-70)		(7-25-72)		(7-25-72)		(7-25-72)		(7-25-72)	
ORIGINAL IMAGE TYPE	FALSE COLOR IR		B&W TRANS.		B&W TRANS.		B&W TRANS.		CIR ENHAN. TR. [b]	
INTERPRETED IMAGE TYPE	CIR TRANS.		B&W PRINT		B&W PRINT		B&W PRINT		COLOR PRINT [c]	
ORIGINAL FORMAT	9 X 9 in.		9 X 9 in.		9 X 9 in.		9 X 9 in.		9 X 9 in.	
INTERPRETATION FORMAT	9 X 9 in.		16 X 20 in.		16 X 20 in.		16 X 20 in.		16 X 16 in.	
IMAGE SPECTRAL RANGE	.4 - 0.9μ		0.5 - 0.6μ		0.6 - 0.7μ		0.8 - 1.1μ		.5-.7 & .8-1.1	
ORIGINAL IMAGE SCALE	1:120,000		1:1,000,000		1:1,000,000		1:1,000,000		1:1,000,000	
OBJECT RESOLUTION	20-30 FT.		200-300 FT.		200-300 FT.		200-300 FT.		200-300 FT.	
INTERPRETATION RESULTS	D*	I**	D*	I**	D*	I**	D*	I**	D*	I**
FOREST RESOURCES										
Coniferous Forests	●●●	●●●	●●	●●	●●	●●	●●	●	●●●	●●
A. High Elevation Red Fir Forest	●●●	●●●	●●	●	●●●	●●●	●	●	●●●	●●
B. Westside Intermediate Mountain Conifer	●●●	●●●	●●	●●	●●●	●●	●●	●	●●	●●
BB. Eastside Intermediate Mountain Mixed Conifer	●●	●●	●●	●	●●	●	●	●	●	●
C. Eastside Intermediate Pine-Scrub Forest	●●●	●●●	●●●	●●	●●●	●●	●	●	●●	●●
D. Eastside Northern Juniper Woodland	●●	●●	●	●	●	●	●	●	●	●
E. Eastside Timberland-Chaparral Complex	●●●	●●●	●●	●●	●●●	●●	●	●	●●●	●●
Hardwood Forests	●●●	●●●	●●	●	●●	●●	●	●	●●	●
F. Intermediate Mountain Xeric Hardwoods	●●●	●●●	●●	●	●●	●	●	●	●●	●●
G. Westside Foothill Pine-Oak Woodland	●●●	●●●								
GG. Westside Foothill Oak Woodland-Grass	●●●	●●●								
GC. Westside Foothill Oak Woodland-Chaparral	●●●	●●●								
GGC. Westside Foothill Oak Woodland-Grass-Chaparral	●●●	●●●								
H. Mixed Mesic Hardwood Communities	●●●	●●●	●	●	●	●	●	●	●	●
I. Westside Foothill Mixed Hardwood-Conifer Forest	●●●	●●●								
NON-FOREST RESOURCES										
Chaparral	●●●	●●●	●●	●●	●●	●●	●●	●	●●●	●●
J. Westside Valley Front Foothill Chaparral	●●●	●●●								
K. Westside Intermediate Mountain Chaparral	●●●	●●●	●●	●	●●●	●●	●●	●	●●●	●●
KK. Eastside Intermediate Mountain Chaparral	●●●	●●●	●●	●●	●●●	●●	●●	●	●●●	●●
L. Eastside Valley and Basin Front Sagebrush Scrub	●●●	●●●	●●●	●●●	●●●	●●	●	●	●●●	●●
Grassland-Meadow-Marshland Complex	●●●	●●●	●●	●	●●	●	●	●	●●●	●●
M. Subalpine Grassland										
N. Intermediate Interior Valley Xeric Grassland	●●●	●●●	●●●	●●	●●●	●●●	●	●	●●●	●●●
O. Mesic Meadow Complex	●●●	●●●	●●	●	●●	●●	●	●	●	●
P. Freshwater Marshland	●●●	●●●	●●●	●●	●●●	●●	●●	●	●●●	●●●
AGRICULTURAL AND RANGELAND RESOURCES										
Q. Mesic Cultivated Croplands	●●●	●●●	●●	●	●●●	●●●	●●●	●●●	●●●	●●●
R. Mesic Rangeland	●●●	●●●	●●	●●	●●	●●●	●	●	●●	●●●
S. Xeric Eastside Grassland-Scrub Rangeland	●●●	●●	●●●	●●	●●●	●●●	●	●	●●●	●●●
OTHER LANDSCAPE FEATURES										
T. Forest Plantation Sites	●●●	●●●	●●●	●●	●●●	●●	●	●	●●●	●●
U. Urban-Residential-Commercial Sites	●●●	●●●	●●	●	●●●	●	●	●	●●	●
V. Exposed Soil	●●●	●●●	●●	●●	●●	●●	●	●	●●	●●
W. Exposed Bedrock	●●●	●●	●●●	●●	●●	●●	●	●	●●	●●
WB. Basalt	●●●	●●●	●●	●	●●	●	●	●	●●●	●●●
WA. Andesite	●●●	●●	●●	●	●●●	●●	●	●	●●	●
WR. Rhyolite	●●	●●								
WP. Pyroclastics	●●●	●●	●●	●	●●	●	●	●	●●	●●
WG. Granite	●●●	●●●	●●	●	●●●	●●	●	●	●●	●●
WU. Ultrabasics	●●●	●●●	●●	●	●●●	●	●	●	●●●	●●
WS. Sedimentary	●●●	●●●	●●	●	●●●	●●●	●●	●	●●	●●●
WM. Metavolcanics	●●	●●	●	●	●	●	●	●	●	●
HYDROLOGIC RESOURCES										
X. Standing Water	●●●	●●●	●●	●●	●●●	●●●	●●●	●●●	●●●	●●●
Y. Running Water	●●●	●●●	●	●	●●	●●	●	●	●●	●●
Z. Snowpack	●●●	●●●								
MISCELLANEOUS FEATURES										
ZA. Recent Fire Scar	●●●	●●●	●	●	●●	●	●●●	●●	●●●	●●
ZB. Main Highway	●●●	●●●	●●●	●●●	●●●	●●●	●	●	●●●	●●
ZC. Landslide Scar	●●●	●●●	●●	●	●●●	●	●	●	●●	●●
ZD. Logging Roads	●●●	●●●	●●	●●●	●●●	●●●	●	●	●●	●●

* DETECTION .... THE ABILITY TO DISCRIMINATE AN IMAGE ENTITY FROM THE SURROUNDING TONE MATRIX.

** IDENTIFICATION .... THE ABILITY TO CLASSIFY AND ASSIGN A NAME TO AN IMAGE DETERMINED BY ITS UNIQUE CHARACTERISTICS SUCH AS COLOR, TONE, TEXTURE, SHAPE, PATTERN, SIZE, ASSOCIATION OR OTHER QUALITY.

[a] Feasibility of image identification includes consideration of sequential imagery.
[b] MSS color-combined enhanced image transparency.
[c] The enlarged print used in this interpretation was fifth generation.

Cultivated Croplands and standing water are identifiable.

Preliminary results on a regional basis indicate interpreter ability to identify the following wildland resources on the MSS 4-5-7 false-color combined image: Intermediate Interior Valley Xeric Grassland, Freshwater Marshland, Mesic Cultivated Croplands, Mesic Rangeland, Xeric Eastside Grassland-Scrub Rangeland, Exposed Basalt Bedrock, sedimentary rock, and standing water. Future quantitative testing at varied image resolution levels, coordinated with multidate sequential analysis, should establish the validity of these preliminary conclusions.

Projected interpretation time and associated costs required for producing vegetation/terrain resource maps from both high altitude and ERTS-1 imagery of the Feather River Watershed Region are presented in Table 4.3. Approximately sixty high altitude images are needed to compile the complete regional map, as compared with one ERTS-1 image. The total time and costs required for imagery interpretation, including resource type classification, has been estimated to be seven times greater on high altitude than on ERTS-1. Of importance to these projected results is the significant difference in resource information content between these two types of imagery. The significance of this resource information loss (when ERTS-1 imagery is compared to high flight imagery), however, remains to be assessed, based on user requirements, image quality, interpreter acuity, multidate sequential analysis, and multi-purpose goals.

TABLE 4.3 PROJECTED INTERPRETATION TIME AND COSTS OF REGIONAL FEATHER RIVER WATERSHED IMAGE ANALYSIS

TASK	HIGH ALTITUDE CIR TRANSPARENCY (9 x 9 in.)	ERTS-1 COLOR ENHANCED FALSE-COLOR ENLARGED PRINT (16 x 16 in.)
DELINEATION OF WATERSHED BOUNDARY (2.5 MILLION ACRES)	3.0 HOURS	0.5 HOURS
PLOTTING EFFECTIVE AREAS	5.0 HOURS	0.0 HOURS
DELINEATION OF HOMOGENEOUS AREAS	48.0 HOURS	3.0 HOURS
PHOTO INTERPRETATION TRAINING & TESTING	6.0 HOURS	2.0 HOURS
RESOURCE TYPE CLASSIFICATION	210.0 HOURS	30.0 HOURS
TOTAL INTERPRETATION TIME REQUIRED	272.0 HOURS	35.5 HOURS
HOURLY WAGE	$7.00/HOUR	$7.00/HOUR
TOTAL INTERPRETATION COSTS	$1,904.00	$248.50
TOTAL COST/ACRE	0.07¢	0.0098¢
COST RATIO	7	1

4.2 INTENSIVE STUDY AREA ANALYSES

4.2.1 Davis Lake Study Area

a. Manual Interpretation

Methods and Procedures: The approach used toward developing manual techniques for ERTS-1 imagery analyses has initially been confined to the Bucks Lake and Davis Lake intensive study areas. Although quantitative testing of interpreter results remains the main objective of ERTS-1 investigations, preliminary ERTS-1 interpretation analysis has dealt with developing methods of extracting interpretable data from the Davis Lake intensive test site areas on the MSS color combined image. The techniques used involve enlarging a copy positive transparency of the area (320,000 acres) to approximately 8 x 10 inch size by projecting the image onto a sheet of white paper where apparent color tone differentiation can be delineated. This technique is similar to the one used for delineating tone differences on an enlarged photo overlay; however, greater tone differentiation, image resolution, and ease of scale change enable the former technique to provide greater versatility, and the resultant image contains more detail and better tone quality.

The technique of recognizing and delineating analogous areas on ERTS-1 and high altitude imagery interpretations is illustrated in Figures 4.7 and 4.8. Homogeneous color-tone area delineations, similar to those tones apparent in Figure 4.7, are compared with the ground-controlled classified map data (Figure 4.7 and Figure 4.8, part 4). In Figure 4.7 the ground-controlled high altitude CIR interpretations

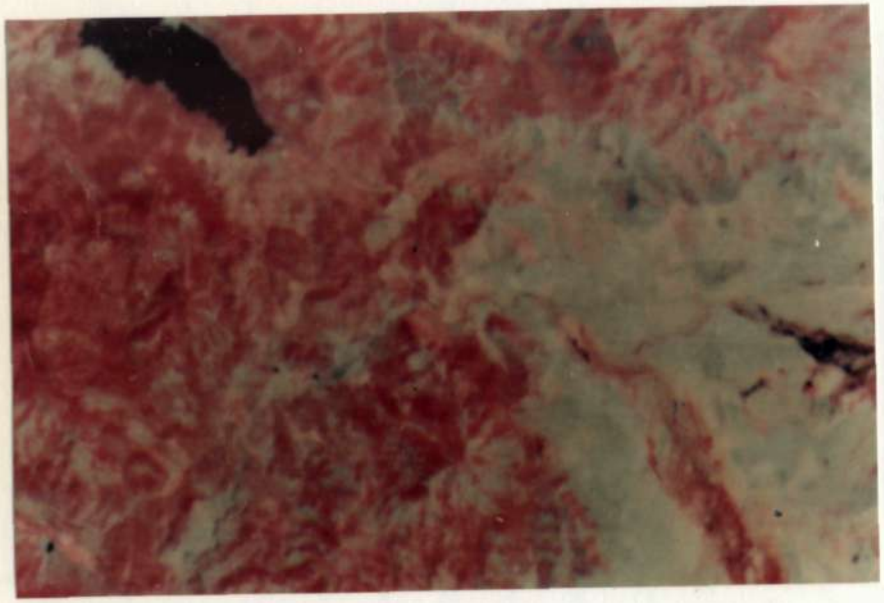


Figure 4.7a ERTS-1 MSS false color combined bands nos. 4-5-7 of Davis Lake intensive study area. The approximate scale of this enlarged image is 1:250,000.

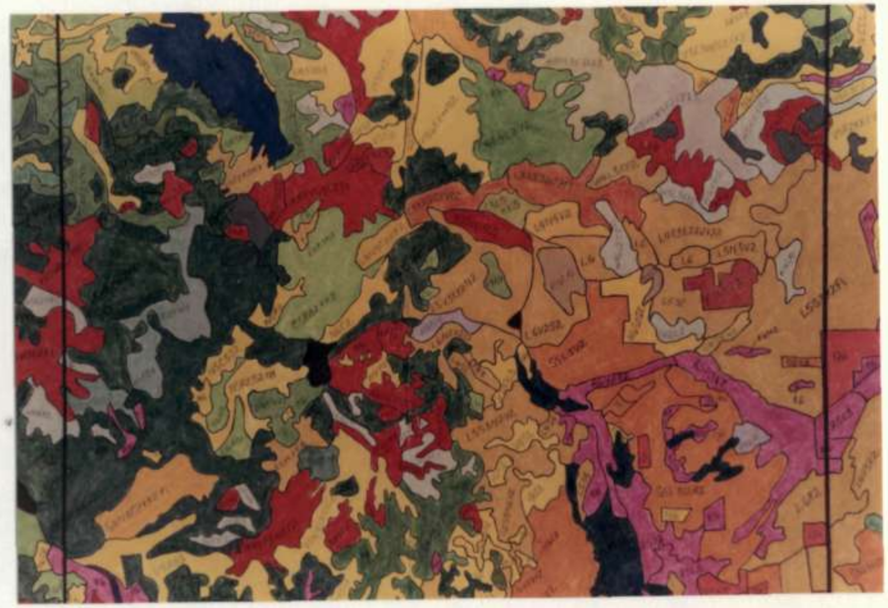


Figure 4.7b High altitude false color infrared ground controlled photo interpretations of the Davis Lake study area, color coded to facilitate vegetation-terrain type differentiation and classification. The approximate scale of this rendition is 1:250,000.

of the wildland resources have been color coded for ease of broad vegetation/terrain type identification. Figure 4.8, part 1, demonstrates the ability of an interpreter to delineate many color-tone areas on the projected ERTS-1 image, which might be called micro-delineations. The areas are amalgamated (Figure 4.8, part 2) into larger contrasting, broadly inclusive, homogeneous color-tone areas, which might be called macro-delineations (Figure 4.8, part 3). These areas may closely resemble analogous areas delineated on high altitude ground controlled interpretations (Figure 4.8, part 4), depending on the degree of color contrast among image areas (color-tones) and other qualifications such as consistency of texture within delineated areas, mottling characteristics, interpreter variability, and scale and map rectification considerations. Figure 4.8, part 5, illustrates the ERTS-1 macro delineations with ground-controlled vegetation/terrain classifications transferred to the analogous areas. This rendition thus provides a useful means for performing resource interpretations from the ERTS-1 projected image.

<u>Results and Discussion</u>: The technique described above has enabled a preliminary ERTS-1 evaluation to be made of color-tone variations within the Davis Lake area, which relate to the different imaging characteristics of the classified resources present. Table 4.4 indicates the results of an investigation where the interpreter performed Munsell Color Notation comparison determinations on approximately 50 percent of the macro-delineated color-tone areas on the ERTS-1 image. The Munsell color system ranges of hue, value, and chroma, the

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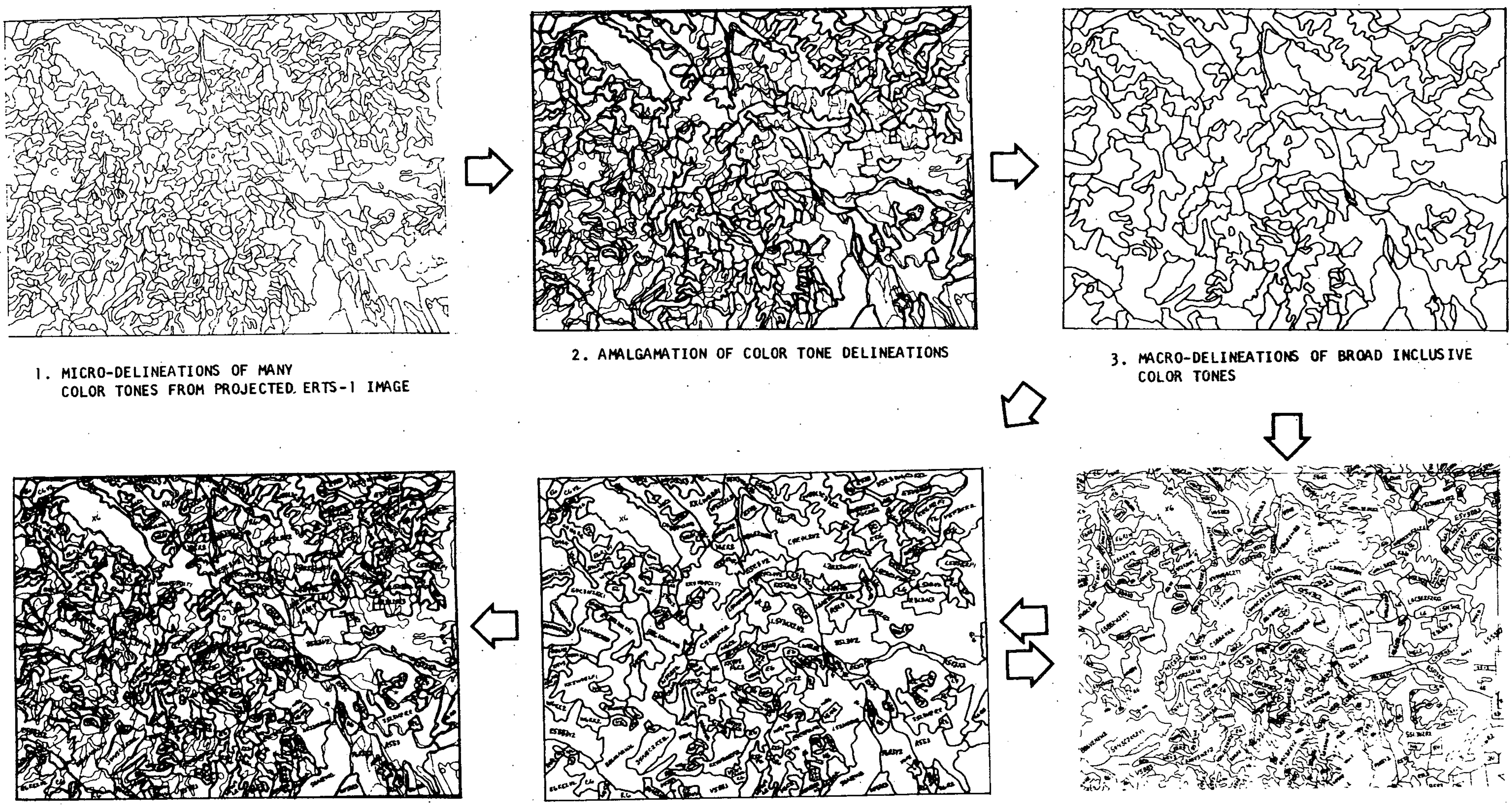
Figure 4.8 ANALYSIS TECHNIQUE OF AN ERTS-1 IMAGE (MSS 4-5-7) OF THE DAVIS LAKE INTENSIVE TEST SITE

PROGRESSIVE HOMOGENEOUS COLOR TONE AREA DELINEATIONS ARE COMPARED WITH GROUND CONTROLLED CLASSIFIED MAP DATA DERIVED FROM HIGH ALTITUDE C.I.R. INTERPRETATIONS



1. MICRO-DELINEATIONS OF MANY COLOR TONES FROM PROJECTED ERTS-1 IMAGE

2. AMALGAMATION OF COLOR TONE DELINEATIONS

3. MACRO-DELINEATIONS OF BROAD INCLUSIVE COLOR TONES

4. GROUND CONTROL VEGETATION-TERRAIN MAP DERIVED FROM HIGH ALTITUDE C.I.R. MANUAL INTERPRETATIONS

5. ERTS-1 MACRO-DELINEATIONS WITH TRANSFERRED VEGETATION-TERRAIN MAP CLASSIFIED DATA

6. OVERLAY OF COMBINED DATA (1 & 5)

TABLE 4.4

QUALITATIVE RESULTS OF AN INTERPRETATION STUDY PERFORMED ON ERTS-1 IMAGERY OF COLOR TONE VARIATION AMONG RESOURCES WITHIN THE DAVIS LAKE INTENSIVE STUDY AREA

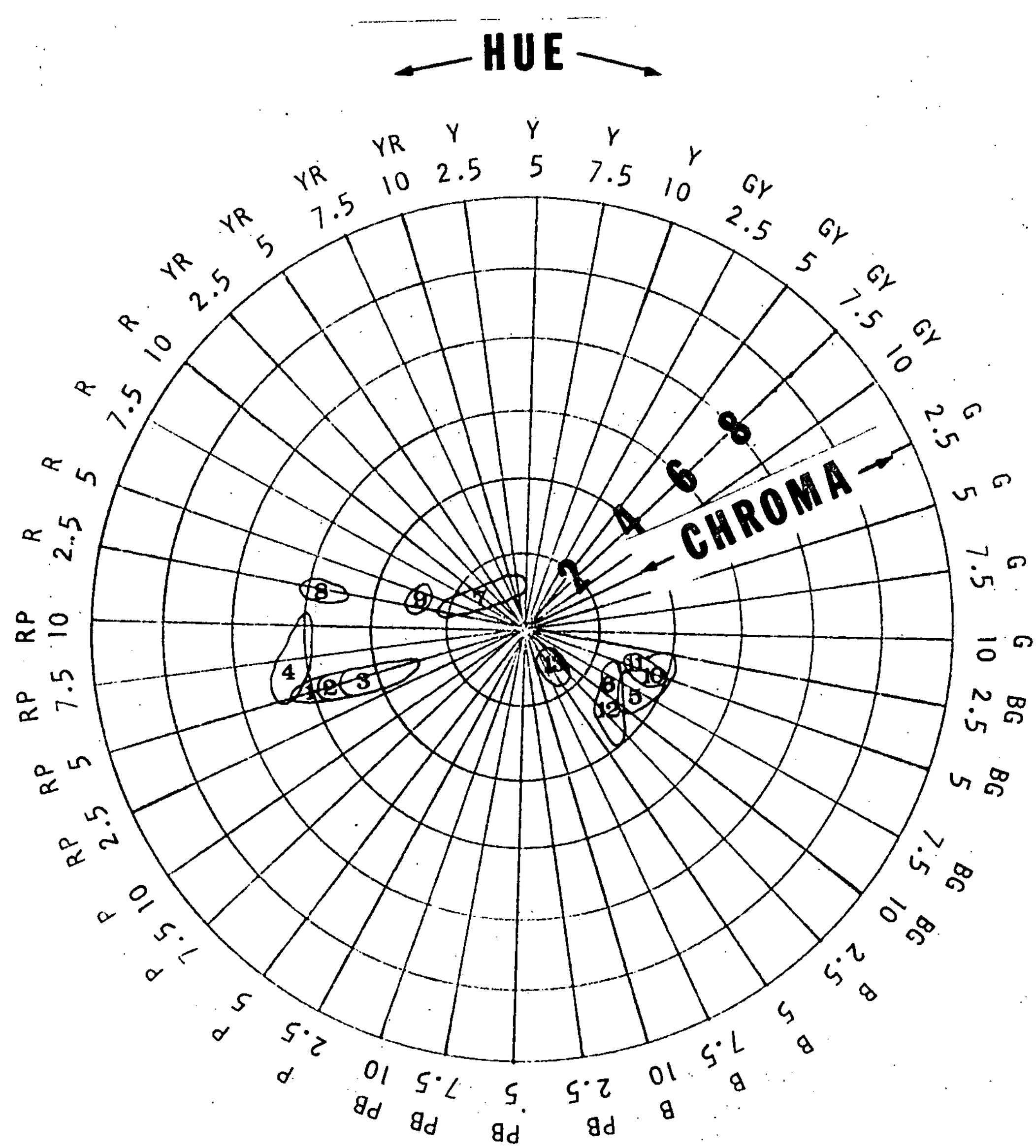
CODE NO.	RESOURCE	N	HUE RANGE	VALUE RANGE	CHROMA RANGE	ISCC-NBS ASSOCIATED COLOR CHIP NAME AND NO.
1	Eastside Intermediate Mountain Mixed Conifer	6	5-6 RP	3-5	3-7	grayish purplish red (#262)
2	Eastside Timberland Chaparral Complex	18	5-6 RP	3-5	3-6	(#262 and dark purplish red #259)
3	Eastside Intermediate Pine-Scrub Forest	8	5 RP	4-6	3-5	light grayish purplish red (#261 dark purplish pink (#251)
4	Eastside Intermediate Mountain Chaparral	6	5 RP-1R	7-9* 5-6**	6-7	light purplish pink (#249)* moderate purplish pink (#250)* (#251**) and (#262**)
5	Eastside Valley and Basin Front Sagebrush Scrub	10	2.5-10 BG	7-9	3-4	very light bluish green (#162) very light greenish blue (#171) light bluish green (#163) light greenish blue (#172)
6	Intermediate Interior Valley Grassland	6	3 BG-2.5 B	7-9	3-4	(#162) and (#163)
7	Intermediate Interior Valley Grassland and Mesic Rangeland	2	5 R-5 Y	7-9	1-2	grayish pink (#8) grayish yellowish pink (#32) yellowish gray (#93)
8	Freshwater Marshland	2	2.5 R	5-6	5-6	grayish red (#19) dark pink (#6)
9	Mesic Rangeland	3	2.5-5 R	7-9	3	grayish pink (#8) moderate pink (#5) pale pink (#7) light pink (#4)
10	Xeric Eastside Grassland-Scrub Rangeland	4	5 BG	7-8	3	(#162), (#163) (#171), (#172)
11	Exposed Soil	3	5 BG	7-9	3-4	(#162), (#163)
12	Exposed Bedrock	4	3 BG- 2.5 B	7-8	3-4	(#162), (#171) (#163), (#172)
13	Standing Water	1	5 B	1-2	1-2	blackish blue (#188)

*sparse cover
**dense cover

ISCC-NBS color name for the thirteen resources studied, and the number of different color comparisons (N) for each resource area investigated, are presented.

Results of this investigation are expressed diagrammatically in Figure 4.9, where the ERTS-1 interpreted color-tone data have been plotted on the Munsell Color System 3-D color solid, which exhibits hue, and chroma. Ranges in color value (i.e., the third dimension in the color solid) for the resources studied are tabulated below the diagram. These ranges, as expressed, enable separation of several resources on the basis of color value or brightness. The resources may be further differentiated on the basis of hue and chroma as illustrated.

These graphic data indicate the possibility of constructing an ERTS-1 photo interpretation key to Feather River Watershed resources within the Lake Davis study area based on color-tone differentiation. Preliminary analysis of interpreter ability to discriminate color-tone differences among resources (see Figure 4.9) indicate that the Eastside Intermediate Pine-Scrub forest (No. 3), Eastside Intermediate Mountain Mixed Conifer type (No. 1) and Eastside Timberland Chaparral Complex (No. 2) are very similar in color-tone qualities as interpreted on the ERTS-1 image. The Eastside Intermediate Pine-Scrub forest does, however, demonstrate a slightly brighter value range, probably associated with lower timber density and volume and higher exposed ground and understory reflectance characteristics within this vegetation type. The Eastside Intermediate Mountain Chaparral type (No. 4), both sparse and dense cover, appears to differ from the other vegetation/terrain



RESOURCE CODE NO.	VALUE RANGE	RESOURCE CODE NO.	VALUE RANGE
1	3-5	7	7-9
2	3-5	8	5-6
3	4-6	9	7-9
4	7-9*	10	7-8
	5-6**	11	7-9
5	7-9	12	7-8
6	7-9	13	1-2

*Sparse **Dense

Figure 4.9 Diagrammatic results of ERTS-1 interpreted color-tone data plotted on a two dimensional rendition of the Munsell Color Solid which exhibits hue and chroma, with the third dimension, value, expressed as ranges of value. Each of the number-coded delineated areas on the diagram represent specific vegetation/terrain resource types. Note both the possibilty and difficulty apparent in the separation of certain resources using color tone criteria. This kind of analysis provides a basis for developing ERTS-1 photo interpretation keys to Feather River Watershed regional resources.

types based on hue (reddish), chroma, and value. Freshwater Marshland (No. 8) and Mesic Rangeland (No. 9), though identical in hue, may be separated on the basis of chroma and value, where No. 9 is less saturated and brighter in tone (value range 7-9). Intermediate Interior Valley Grassland and Mesic Rangeland (No. 7) are very light in color value and chroma. Standing water (No. 13) is characteristically blackish blue on this image and is distinctively separated from other resources on its dark color value (1-2) alone. Both the Intermediate Interior Valley Grassland (no. 6) and Exposed Bedrock (No. 12) are very similar in color-tone, indicating difficulty in identification and separation on this basis alone. The above resources, No. 6 and No. 12, are also difficult to separate from Exposed Soil (No. 11) in as much as their reflectance characteristics are very similar, and the resource units are often not clearly defined in nature. The Eastside Valley and Basin Front Sagebrush Scrub (No. 5) probably cannot be separated from the Xeric Eastside Grassland Scrub Rangeland (No. 10) on a color-tone basis, and may be confused with type No. 5 or No. 11.

These preliminary results, specific to the image under investigation, remain to be tested quantitatively both on this same image (fifth generation copy positive transparency) and on subsequent ERTS-1 positive multidate transparencies. Future testing of manual interpretation results should further demonstrate the ability of the image analyst to discriminate color-tones and corresponding vegetation/terrain types on ERTS-1 imagery dependent on image quality, resolution, season, development of useful interpretation guides, and visual acuity.

b. Automatic Interpretation

Methods and Procedures: The Automatic Image Classification and Data Processing Unit within the Forestry Remote Sensing Laboratory has several ERTS-oriented hardware and software projects that are now operational:

Hardware

color display system

Software

ERTS to local reformation

intensive test site data extraction

spectral training data extraction

CALSCAN modification

In addition, the color display portion of the Forestry Remote Sensing Laboratory computer facility is now operational. This display allows the storage and viewing in color of up to 3 bands of digital tape images in common register. Figure 4.10 shows a block diagram of the color display system currently being used. As an integral part of the computer system (see Figure 4.11), the display can handle line drawings, ERTS-1 images, CALSCAN output images, and scanner images. The operator has control of the input to each of the color guns in the color TV monitor. Thus, he can display simulated CIR images, real-color or other false-color images. Additional flexibility afforded by this system is demonstrated in Figure 4.12. For example, the image at the top in Figure 4.12 shows the display of 1/8 of an ERTS-1 frame (Davis Lake area) from computer compatible tape. From this display, intensive

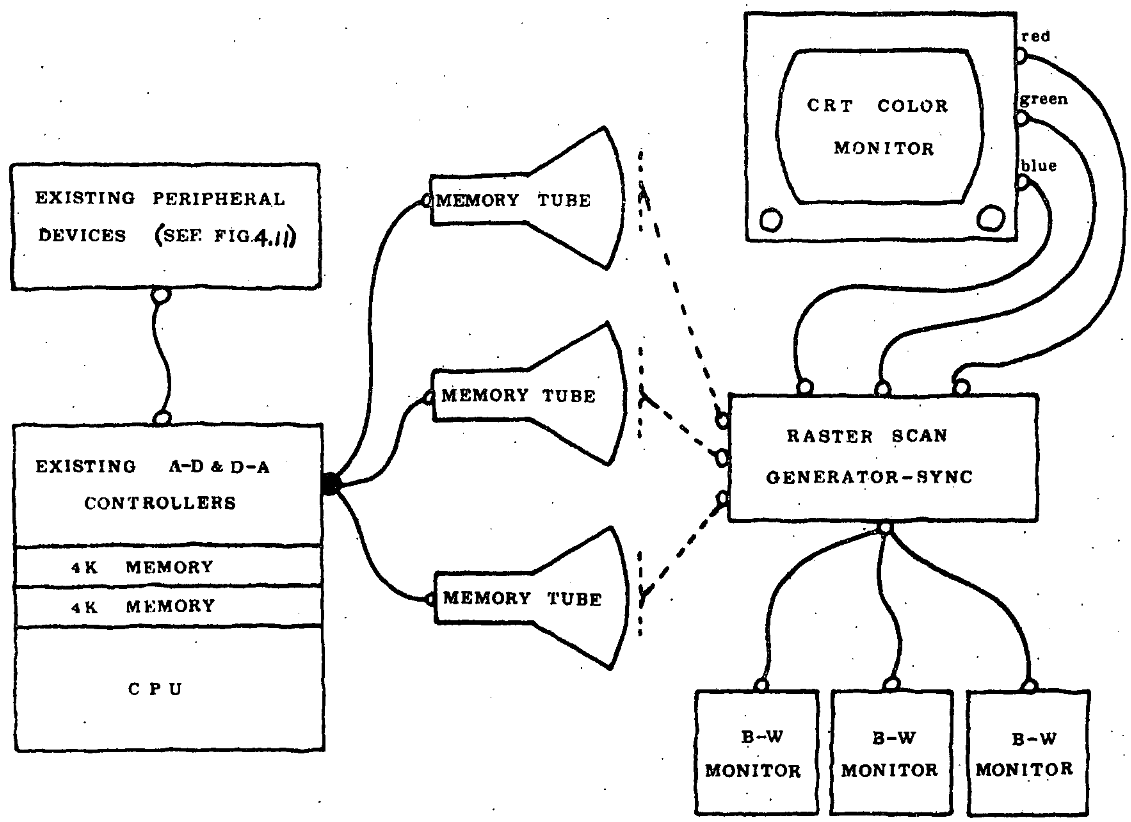


Figure 4.10 Block diagram of the color display portion of the terminal display computer system. The system allows the interactive display of computer generated line drawings and computer processed images.

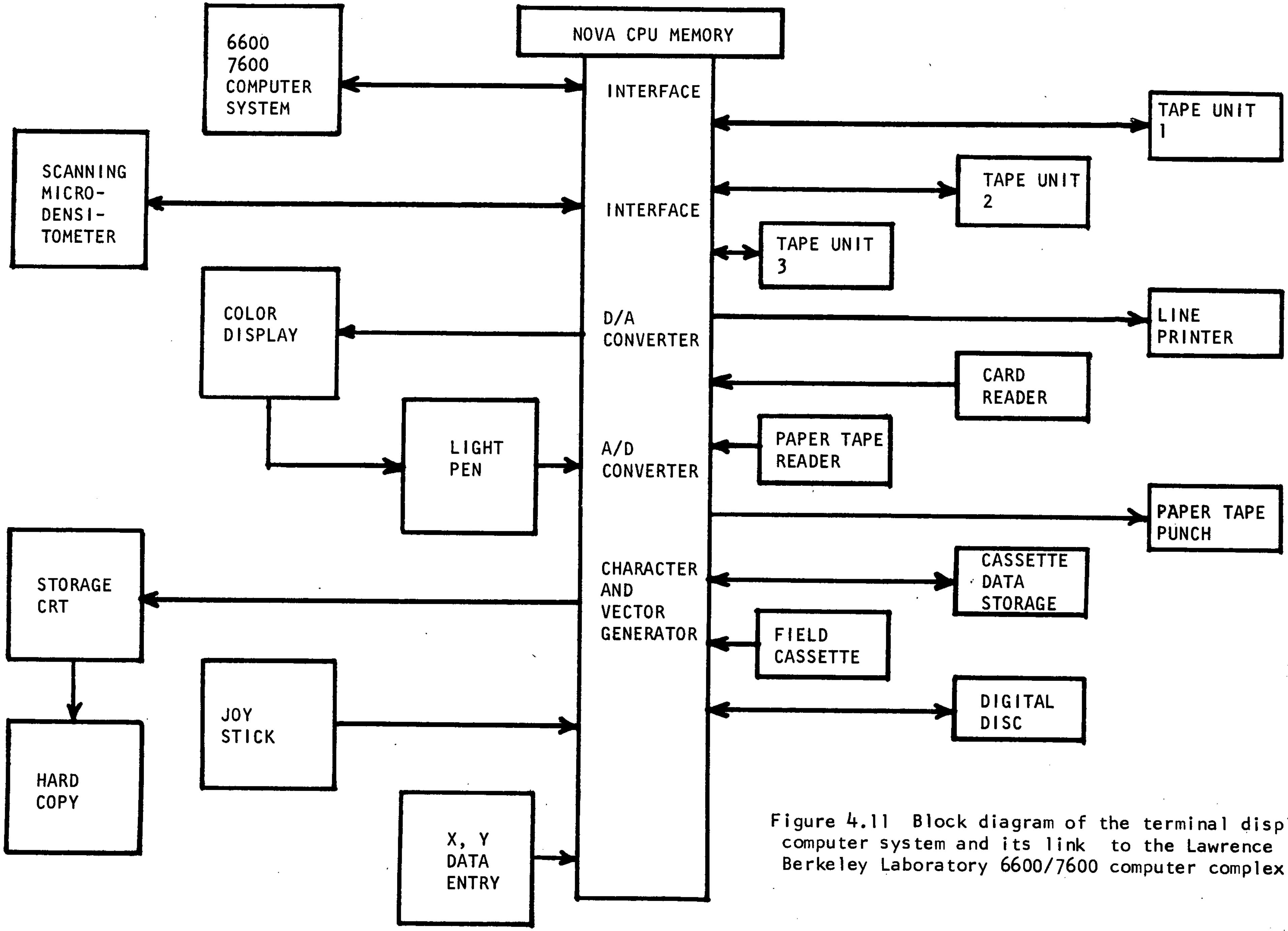


Figure 4.11 Block diagram of the terminal display computer system and its link to the Lawrence Berkeley Laboratory 6600/7600 computer complex.

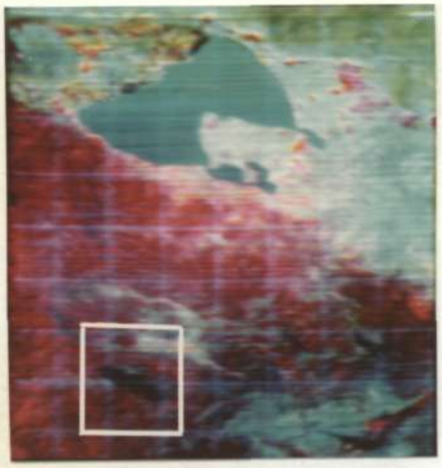


Figure 4.12a An 810 horizontal by 1024 vertical array of picture elements (1/8 of an ERTS-1 image) is displayed on the color monitor. Here the red color represents band 7, the green color represents band 5, and the blue color represents band 4 from bulk MSS computer compatible tapes.

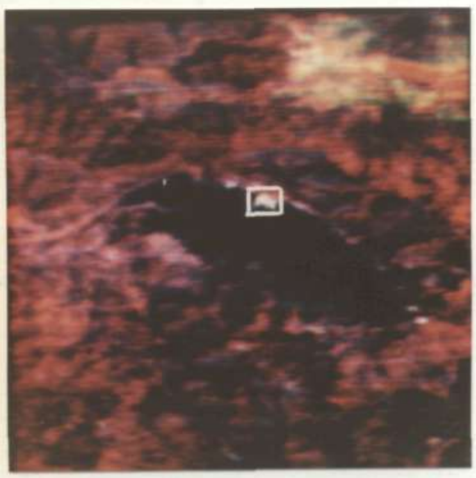


Figure 4.12b An intensive test site has been extracted for enhancement and analysis. This 220 by 220 array of picture elements demonstrates the resolution of ERTS-1 digital tape and color enhancemen

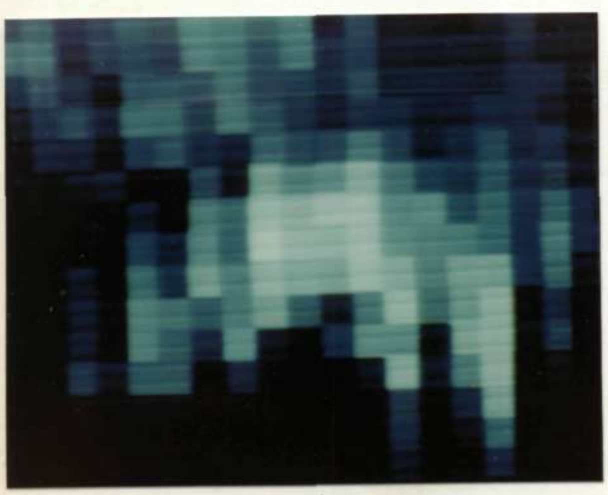


Figure 4.12c A 20 by 20 array of picture elements has been extracted from the digital tape used in producing the array in Figure 4.12b and expanded so that each e -ment is represented by one of the squares This array can be used to check image registration and spectral information.

test sub-images can be selected and displayed (see middle and bottom photo in Figure 4.12). After the intensive study areas have been selected, spectral data can be extracted from training areas for use in CALSCAN, and classification results can then be displayed for correlation with ground truth (see Figure 4.13). The system is also useful for image registration, verification of data, and color enhancement.

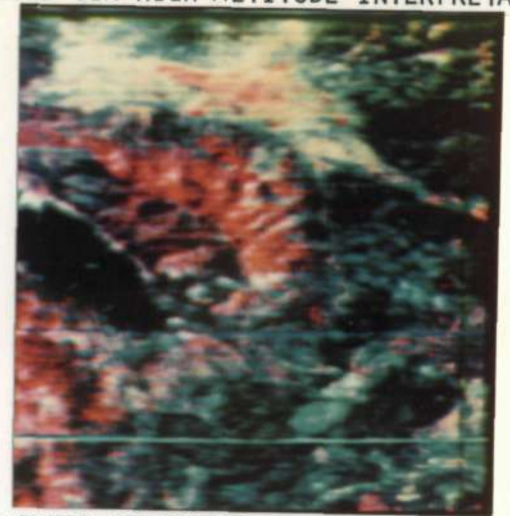
In order to reduce the cost of processing ERTS-1 data, several pre- and post-classification steps are performed on the Forestry Remote Sensing Laboratory "mini" computer. The following steps can be taken: (1) the original NDFP tapes are reformatted to local standards, (2) the intensive study areas are selected from the bulk tape, (3) spectral training data are extracted from the intensive study sites, and (4) classification results are displayed on the color display. Further examples of the capabilities of this computer system are shown in the agriculture section of this report.

Results and Discussion: A computer-generated image of ERTS-1 MSS data, selected directly from digital tapes, is seen in Figure 4.13. Each of the 3 MSS bands may be assigned a specific color that is combined electronically to produce the additive color display image on the color TV monitor. In this example, band 4 has been assigned a green color, band 5 -- blue, and band 6 -- red. Figure 4.13 represents homogeneous color-tone area delineations drawn in an overlay format from the TV monitor image, and corresponds generally to analogous areas delineated on the CIR ground-controlled high altitude photos.

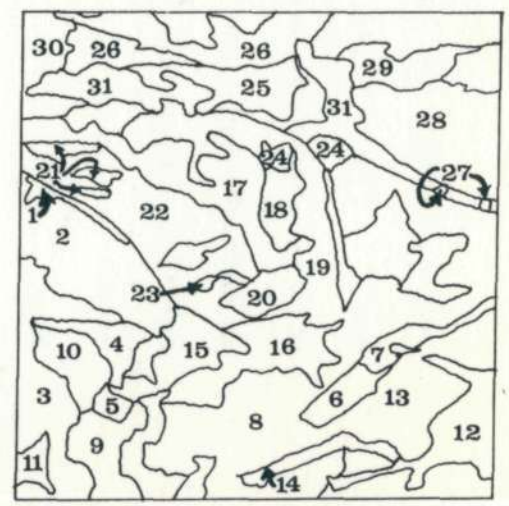
AREA DELINEATION CODE NO.	ANALAGOUS GROUND CONTROLLED CIR INTERPRETED CLASSIFIED RESOURCE COMPOSITION	DOMINANT INCLUSIVE VEGETATION-TERRAIN TYPES DELINEATED
1.	N6	Xeric Grassland
2.	X6	Standing Water (Lake Davis)
3.	E6R1V1;E5KK2V2	Eastside Timberland Chaparral
4.	C5R3N2	Eastside Pine-Scrub Forest
5.	KK6	Eastside Mt. Chaparral
6.	L4N4C2KK2	Sagebrush Scrub-Xeric Grassland
7.	L4KK4C2VP2	Sagebrush Scrub-Mt. Chaparral
8.	C5BB2KK2	Eastside Pine-Scrub Forest
9.	BB6V2N2W2	Eastside Mt. Mixed Conifer
10.	E6V1	Eastside Timberland Chaparral
11.	E5BB2W2KK1	Eastside Timberland Chaparral
12.	L5V3KK2N2	Sagebrush Scrub-Exposed Soil
13.	E6V2N2	Eastside Timberland Chaparral
14.	N6C2	Xeric Grassland
15.	KK5V2C2	Eastside Mt. Chaparral
16.	KK4VG4C2T1	Eastside Mt. Chaparral - Exposed Granite Bedrock
17.	KK6W2BB1	Eastside Mt. Chaparral
18.	VP5KK3L3	Exposed Pyroclastic Soil - Eastside Mt. Chaparral
19.	E4V2WP2	Eastside Timberland Chaparral
20.	KK4VA4;V6KK2;V5E3	Eastside Mt.Chaparral,Exposed Soil,Exposed Soil-Eastside Mt. Chaparral
21.	W6C2	Exposed Bedrock
22.	C4BB4W2N2	Eastside Pine-Scrub Forest-Eastside Mt. Mixed Conifer
23.	WA6A2	Exposed Bedrock
24.	WP5KK3L3	Exposed Pyroclastic Bedrock-Eastside Mt. Chaparral
25.	R6H2S2V1	Mesic Rangeland
26.	S4N3VS2R1	Xeric Eastside Grassland-Scrub Rangeland-Xeric Grassland
27.	R6	Mesic Rangeland
28.	E6V2;E5W2L1;WB4L3E3KK2	Eastside Timberland Chaparral, Exposed Basalt Bedrock - Sagebrush Scrub
29.	WA6C2V2	Exposed Andesite Bedrock
30.	BB5V2	Eastside Mt. Mixed Conifer
31	S4N3VS2R1	Xeric Eastside Grassland-Sagebrush Scrub Rangeland-Xeric Grassland

FIGURE 4.13

ANALAGOUS AREA DETERMINATIONS WITHIN THE DAVIS LAKE INTENSIVE TEST SITE BETWEEN COMPUTER GENERATED COMPATABLE MSS ADDITIVE COLOR DATA, DISPLAYED ON A COLOR T.V. MONITOR, AND GROUND CONTROLLED CIR HIGH ALTITUDE INTERPRETATIONS



A. COMPUTER GENERATED MSS ADDITIVE COLOR DATA DISPLAYED ON A COLOR T.V. MONITOR. COLOR ASSIGNMENTS: BAND 4-GREEN, BAND 5-BLUE, BAND 7-RED.



B. ANALAGOUS RESOURCE AREA DELINEATIONS CODED FOR IDENTIFICATION.

These delineations (Figure 4.13B) have been coded by consecutive number to enable interpretation of the automatically processed image. The adjacent table in Figure 4.13 provides the analogous area ground-controlled resources composition, according to the classification scheme previously described, as well as the dominant inclusive vegetation/terrain types within these analogous areas. This information readily facilitates inspection of the automatically processed image. It is apparent from the rendition provided, that Mountain Chaparral (Nos. 5, 15, and 17) and vegetation/terrain types wherein Chaparral comprises a significant amount of cover (Nos. 3, 10 and 15), are highly reflective in the infrared band in as much as the assigned red color predominates. Lake Davis (No. 2) is readily identifiable from its continuous tone and texture on band 5 which was assigned a blue color on the TV monitor. The Sagebrush-Scrub type (No. 6) appears green on the processed image, confirming high reflectance on band 4. Generally, more dense Mixed Conifer Forest vegetation types (Nos. 8, 13, 19, 28 and 30) appear dark blue while Xeric Eastside Grassland-Sagebrush Scrub Rangeland (No. 31) appears as a mottled light yellow-blue, and Mesic Rangeland appears red against the light yellow-blue color background.

The importance of this type of manual interpretation of automatically processed and displayed imagery of selective sites, lies in the necessity of rationally programming automatic output, whether in digital or TV displayed format. Only through meaningful ground controlled comparisons, similar to what has been done in this example, will future operational automatic processing capabilities applied to wildland mapping and analyses be achieved.

4.2.2 Bucks Lake Study Area

a. Methods and Procedures

The approach for making preliminary evaluations of ERTS-1 imagery within the Bucks Lake study area was slightly different than the one used at Davis Lake. For example, a study was recently completed for the Bucks Lake area in which forest land classification results derived from conventional black-and-white photos were compared with results obtained from ultra-high altitude, small scale, false-color infrared photos. Consequently, during the preliminary stages of the ERTS-1 experiment, it was feasible to analyze an ERTS-1 color composite image in the same manner, whereby results derived from the ERTS data were compared with those previously obtained from the conventional black-and-white and high altitude, false-color infrared photos.

Specifically, an area roughly 50,000 acres in size was first classified with the aid of conventional photos, then it was classified using high flight photos, and, lastly, it was classified using ERTS-1 data. Thus, three sets of imagery were used in the analysis: (1) seventy-eight U.S. Forest Service 9 x 9 inch black-and-white, scale 1:15,840 photos, (2) three 9 x 9 inch false-color infrared, scale 1:120,000 photos (procured by the NASA RB57F aircraft in July, 1969) and (3) a small portion of one 8 x 10 inch ERTS-1 MSS color composite image (bands 4, 5 and 7), enlarged to a scale of 1:125,000 (see Figure 4.14). After a skilled image analyst had properly prepared each set of imagery for interpretation (i.e., plotting the watershed boundary, plotting effective areas and training himself to recognize

Figure 4.14 The three sets of imagery used in the Bucks Lake study are shown here. A mosaic of the seventy-eight U.S. Forest Service, black-and-white- photos (original scale 1:15,840) is shown on the left. One of the three high flight, false-color infrared photos (original scale 1:120,000) is shown in the middle, and a portion of the ERTS-1 MSS color composite image (original scale 1:1,000,000) is shown on the right. Interpretation results derived from each set of imagery are illustrated in Figure 4.15, and a discussion of the analysis of the results is given in the accompanying text and in Figures 4.16 and 4.17. In addition, the times and costs associated with working with each set of imagery shown here are presented in Table 4.5.

the image characteristics for each important terrain type or condition occurring with the area), he proceeded to stratify and classify on each set of imagery land units that appeared to have homogeneous characteristics. It should be noted, however, that several months elapsed between the times of the three interpretation tasks, and the ERTS-1 image was the one interpreted most recently. Thus, the possibility of interpreter bias (i.e., interpretation results derived from one type of imagery influencing the results derived from another type) was greatly reduced.

The minimum mapping area for this work was chosen to be 40 acres -- the same as that used by the U.S. Forest Service in this region.

b. Results and Discussion

All classification information interpreted on the seventy-eight conventional photos and the ERTS-1 color composite image was optically transferred to an overlay on the high flight photo. Copies of each of these overlays, including the one for the high flight photo, showing classification boundaries only, are illustrated in Figure 4.15. Note that the black-and-white overlay shows 278 delineated areas, while the high flight overlay shows 265 and the ERTS-1 overlay only 162. Moreover, it should be noted that each delineated area seen on the conventional black-and-white photos and the high flight photos was classified in terms of vegetation/terrain type, vegetation density, aspect and slope. However, the delineated types seen on the ERTS-1 image were classified only in terms of overall vegetation density. No attempt was made with the ERTS-1 image to classify delineated types in terms

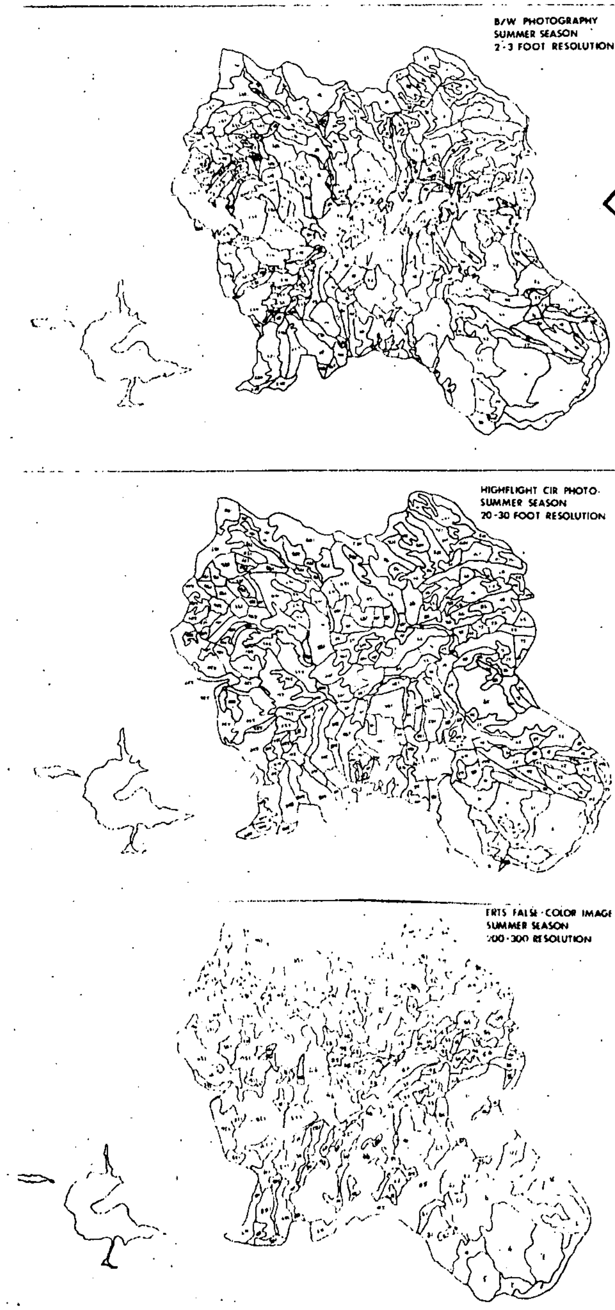


Figure 4.15 Interpretation results derived from the three sets of imagery shown in Figure 4.14 are illustrated here in the form of stratification boundaries. Forestland classification maps made from conventional black-and-white photos, high flight false-color infrared photos and an ERTS-1 image are shown at the top, in the middle and at the bottom, respectively. For the top and middle map, each stratified type was classified in terms of vegetation/terrain type, vegetation density, slope, aspect and elevation. However, the stratified types shown on the bottom map (made from an ERTS-1 image) were classified solely in terms of overall vegetation density.

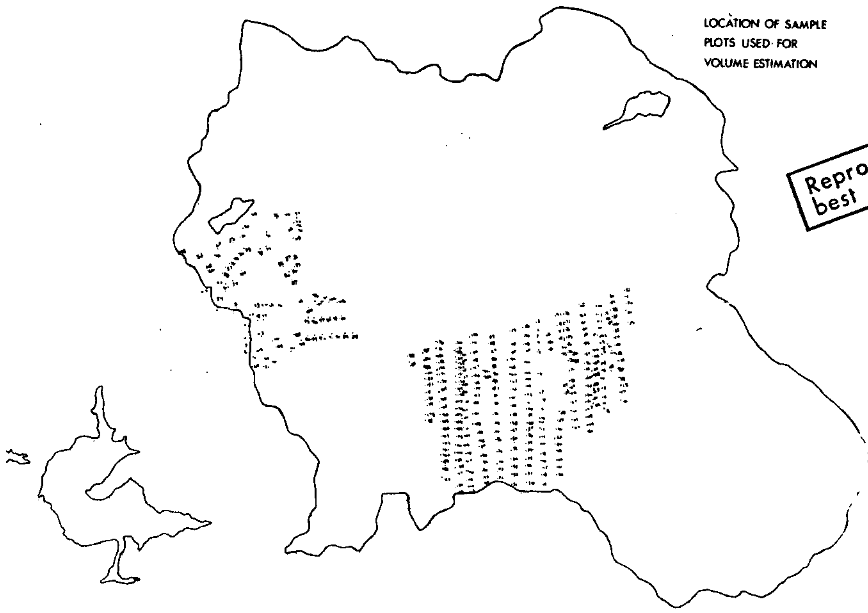
of vegetation terrain type since the image studied was of relatively poor quality (due to the fact that it was a fifth generation copy made from the original) and that only one seasonal state was being observed (i.e., mid-summer). Nevertheless, these preliminary results were evaluated in terms of (1) accuracy of stratification (i.e., placement of boundaries), (2) accuracy of type identification (i.e., overall vegetation density) and (3) interpretation efficiency (i.e., time and costs).

For this preliminary study, it was decided that one way to evaluate the usefulness of the results obtained from the ERTS-1 image would be to compare them with the results derived by conventional means -- which traditionally have been deemed "acceptable" by practicing foresters. Thus, the ERTS-1 map (as well as the high flight map) shown in Figure 4.15 was compared with the map made from conventional black-and-white photos in terms of boundary placement, type identification and interpretation efficiency.

<u>Boundary Placement</u>: Since "ground truth" boundary lines are nearly impossible to derive in a wildland area such as this, it was decided that the most effective way to evaluate boundary placement was to do it indirectly. In other words, evaluate an intended use of the mapped data which is profoundly affected by boundary placement. For example, an estimation of timber volume done by means of stratified sampling is greatly influenced by the placement of stratification boundaries. Thus, if the placement of boundaries is improved, the estimate of timber volume is more reliable and the variance associated with this estimate

is lower. Since timber volume cruise data were collected for a portion of the Bucks Lake study area (11,000 acres) in 1968 and the same area was classified in terms of vegetation density on all three sets of imagery, it was possible to estimate timber volume in two ways: (1) without the aid of either map, and (2) with the aid of each map separately. The results of this analysis, which are shown in Figure 4.16, were surprising. Note that little confidence can be placed in a timber volume estimate made without the aid of stratification (i.e., very high variance occurs) and the estimate is vastly improved when made with the aid of the black-and-white photos. Note also that the estimate made with the aid of the high flight photos compares favorably with the one made with the black-and-white photos, and, in fact, appears to be slightly better. Moreover, the volume estimate made with the aid of ERTS-1 stratification boundaries was surprisingly good even though the variance associated with the estimate was considerably higher than that derived with the aid of the black-and-white photos. When one considers that the interpretation of the ERTS-1 image was done on a fifth generation copy taken during one seasonal state, one must conclude that these preliminary results are encouraging. <u>There is little doubt that the major boundaries between contrasting forest types were properly mapped on the ERTS-1 image, and the subtle boundaries between less contrasting types (and, therefore, the less important boundaries) were the ones which most probably were often misplaced</u>.

<u>Type Identification</u>: To determine the degree to which type identifications (in this case, overall vegetation density) made on the

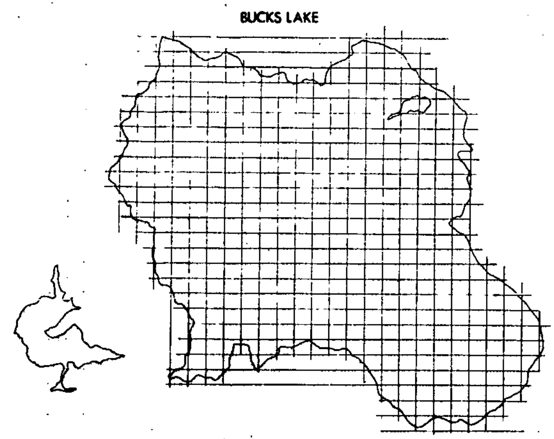


	Using Ground Sampling Only	Using Stratified Sampling (B/W Photos)	Using Stratified Sampling (High Flight Photos)	Using Stratified Sampling (ERTS-1 Image)
Total Acres of Forestland	11,100 acres	11,100 acres	10,900 acres	11,550 acres
Total Number of Strata	0	41	47	22
Total Number of Sample Plots	363	310	335	285
Estimated Timber Volume	133.2 million board-feet	140.6 million board-feet	118.8 million board-feet	128.7 million board-feet
Variance	158.0 million board-feet	6.4 million board-feet	1.9 million board-feet	26.4 million board-feet
Estimated Timber Volume per Acre	12,000 board-feet/acre	12,600 board-feet/acre	10,900 board-feet/acre	11,100 board-feet/acre

Figure 4.16 An indirect method involving an estimation of timber volume was used to evaluate the placement of boundaries shown on each map in Figure 20. The schematic drawing at the top outlines the Bucks Lake study area and shows the location of several hundred timber volume field plots which were established in 1968. The field data were combined with the stratified boundary data derived from each set of imagery, and the calculations shown in the accompanying table were made. See text for an explanation.

black-and-white photos were associated with those made on the high flight photos and the ERTS-1 image, a large number of points were selected throughout the area, and the types within which the points fell were compared (see Figure 4.17). A grid was constructed and, using the same alignment each time, was placed on each of the three classification maps. In this manner, 379 points were located on each map. For each map, the vegetation density category associated with each delineated area within which each point fell was recorded. These results were then tallied in the two-way tables shown in Figure 4.17, in which one axis represents interpretation results from the black-and-white imagery and the other axis shows the results for the same points, but taken from the other two kinds of imagery.

Note that if the frequency distributions for all vegetation type density were identical, the data in these tables would be confined only to the diagonal of joint occurrences, and one would conclude that there is a one-to-one correlation between the two maps in terms of type identification. The extent to which the observed frequencies deviate from such a "theoretical" frequency gives an indication of independence. The percentage values at the bottom of each table indicate, first, the percentage of points, out of the total possible, falling along the diagonal. However, since it was very difficult for the analyst to predict vegetation density on both types of photography, especially in borderline cases, a second percentage value was calculated which allowed inclusion of tallied points which were one density value to each side of the diagonal. It was felt that this would be a better measure of



OVERALL % COVER

High Flight CIR Photo

B/W Photography	1	2	3	4	5	
1	2	0	1	1	0	4
2	0	7	1	2	0	10
3	0	2	2	36	18	58
4	0	0	19	47	81	147
5	0	2	7	24	127	160
	2	11	30	110	226	379

Degree of association (diagonal) = 34%
Degree of association (grouped) = 92%

OVERALL % COVER

ERTS False-color Image

B/W Photography	1	2	3	4	5	
1	0	0	2	0	0	2
2	1	3	2	0	0	6
3	1	5	16	24	10	56
4	1	3	37	64	36	141
5	0	7	24	47	24	102
	3	18	81	135	70	307

Degree of association (diagonal) = 35%
Degree of association (grouped) = 84%

Figure 4.17 With the aid of a grid overlay (top photo) more than 300 points were selected throughout the Bucks Lake study area, and the classification categories within which the points fell as seen on the high flight and ERTS-1 imagery were compared with those seen on the conventional black-and-white photos. In this case, only overall vegetation percent cover was studied, and the results of the analysis are shown in the two-way tables. Note that a grouping of data along the diagonal indicates a high degree of association of type identification results for two different kinds of imagery (i.e., high flight versus black-and-white on the left and ERTS-1 versus black-and-white on the right). The vegetation density categories are: 1 = 0-5%; 2 = 5-20%; 3 = 20-50%; 4 = 50-80%; and 5 = 80-100%.

overall association than would a measure of the one-to-one joint occurrences for each vegetation density category.

Based on (1) a visual comparison of the maps shown in Figure 4.15, (2) an empirical evaluation of the tabular data presented in Figure 4.17 and (3) observations made by the image analyst, one can conclude that <u>there may not be a one-to-one correlation between density categories seen on the three sets of imagery, but there certainly exists a high degree of association</u>.

<u>Interpretation Efficiency</u>: Careful records were kept during each stage of this study in order that interpretation times and costs could be compared. These data have been summarized in Table 4.5. Note that with the black-and-white photos the mere fact of having to work with seventy-eight photos, instead of three when using the high flight CIR images, and only one when using ERTS-1 imagery, meant that much more time was spent delineating the watershed boundary, plotting effective areas, and delineating and classifying the different areas. The high flight photos were much easier than the black-and-white photos to interpret, due to the presence of color, and thus resulted in a reduction in time spent typing and delineating. It should be pointed out, however, that the 1.25 hours spent typing and delineating on the ERTS-1 image only included classifying overall percent density, not vegetation type, aspect, and slope, as was the case with the black-and-white and high flight photos.

Among the conclusions which can be drawn from the figures shown in Table 4.5 are: (1) the use of color high flight photos in place

TABLE 4.5
INTERPRETATION TIME AND COSTS ASSOCIATED
WITH THE BUCKS LAKE STUDY
(50,000 acres)

Task	B/W Photography	High Flight CIR Photo	ERTS False-Color Image
Delineation of watershed boundary	6 hours	1 hour	.5 hour
Plotting effective areas on photos	5 hours	0 hours	0 hours
Interpreter training and testing	3 hours	3 hours	.5 hour
Type delineation and classification	30.5 hours	17 hours	1.25 hours
Total time required	44.5 hours	21 hours	2.25 hours
Hourly wage	$7.00/hour	$7.00/hour	$7.00/hour
Total Interpretation costs (time)	$311.50	$147.00	$15.75
Total cost per acre	.622¢	.294¢	.032¢
Cost ratio	19.8	9.3	1

of conventional black-and-white photos greatly increases interpretation efficiency (e.g., the costs were reduced by more than half), and (2) the ERTS-1 imagery yielded the least amount of information but the delineation was twenty-six times cheaper than that done on the black-and-white photos.

4.2.3 San Pablo Study Area

a. Methods and Procedures

A study was carried out in the California coastal zone to determine the ability of skilled photo interpreters to identify vegetation types in a typical chaparral-hardwood-grassland cover type as seen on ERTS-1 imagery. In addition, the results derived from this study were compared with those obtained from an earlier study which employed optically degraded, simulated ERTS-1 data. In both of these studies, interpretation tests were conducted using the NASA San Pablo Reservoir test site located a few miles east of the Berkeley campus of the University of California.

An ERTS-1 color composite MSS frame #E1003-18175-4/5/7, showing the San Francisco Bay Area and Sacramento River-San Joaquin River Delta was used for interpretation. As shown in Figure 4.18, the image was projected onto a rear viewing screen and enlarged thirty times, thus bringing it to the approximate scale of the imagery used in the previous study. One hundred randomly selected points, in seven environmental categories (Monterey Pine -- MP, Eucalyptus -- E, Mixed Hardwoods -- MH, Chaparral -- C, Grasslands -- G, Water -- W and Non-vegetated -- N), were overlayed

Figure 4.18 This photo example illustrates the procedures used to analyze a portion of an ERTS-1 color composite image showing the San Pablo Reservoir study area. The ERTS-1 image was enlarged approximately 30 times and projected onto a rear viewing screen. An overlay with 100 randomly located points was placed onto the screen and fitted to the enlarged image. After being trained to recognize the image characteristics of each important cover type using an adjacent but similar area, three skilled interpreters attempted to identify the vegetation type within which each point fell. The results of this interpretation test have been quantified and are presented in Figures 4.19 through 4.24.

on the projected ERTS-1 image, and attempts were made to identify the type within which each point fell. Interpretation training aids were prepared using word descriptive keys and examples of imagery including high flight and ERTS-1 imagery. Three interpreters used these training aids and engaged in the test.

b. Results and Discussion

Interpretation results for ERTS-1 images appear in the tables and graphs presented in Figures 4.19 through 4.24. Figure 4.19 shows the cumulative results of three interpreters (data along rows for each type) along with the actual ground truth (data down the columns). In this example, the interpreters correctly identified 21 points falling in Monterey pine; in addition, they called (reading across the two) 6 points Monterey pine that were actually eucalyptus, 15 points Monterey pine that were actually mixed hardwood, 10 points Monterey pine that were actually chaparral, and so on. As can be seen at the bottom of the column marked Monterey pine, there were 27 total points that actually fell within Monterey pine, 6 of these were missed or omitted by the interpreters. The types of omission errors made can be found in the column under the Monterey pine heading. To summarize, the number of correctly identified points for any category are found in the diagonal (at the intersection of the row and column with the same heading). Errors of commission are found along the rows; errors of ommission down the columns. Percent correct is found by dividing the number of correctly identified plots by the total plots in each category and multiplying by 100. Percent commission is the number of

PHOTO INTERPRETER'S RESULTS	GROUND DATA							TOT. SEEN BY P.I.	COM. ERROR	PERCENT COM.
	MP	E	MH	C	G	W	N			
MP	**21**	6	15	10	2		1	55	34	61.8
E	2	**3**	5	6				16	13	81.3
MH	2		**43**	7	3			55	12	21.8
C			13	**14**	18		6	51	37	72.5
G		3	8	10	**49**	3	12	85	36	42.4
W	1					**27**	1	29	2	6.9
N	1			1	3		**4**	9	5	55.6
TOTAL PLOTS	27	12	84	48	75	30	24			
OMISSION	6	9	41	34	26	3	20			
PERCENT CORRECT	77.8	25.0	51.2	29.2	65.3	90.0	16.7			

Figure 4.19 Three photo interpreters working with the ERTS-1 image shown in Figure 4.18 produced the cumulative results shown here. The numbers in the body of the box array of results indicate the total number of points identified by all interpreters. The numbers in the bold-faced diagonal row indicate the number of points identified correctly. Note that MP = Monterey pine, E = eucalyptus, MH = mixed hardwoods, C = chaparral, G = grassland, W = water, and N = non-vegetated.

CATEGORY	IMAGE RESOLUTION (FEET)					ERTS-1
	5-10	50-100	100-200	200-300	300-500	
COMPOSITE (all types)						
Percent Correct	90.3	70.0	63.0	52.7	40.0	53.7
Percent Commission	9.7	30.0	37.0	47.3	60.0	46.3
MONTEREY PINE (MP)						
Percent Correct	100.0	92.6	77.8	51.9	33.3	77.8
Percent Commission	3.6	49.0	41.7	64.1	71.0	61.8
EUCALYPTUS (E)						
Percent Correct	91.7	50.0	75.0	50.0	66.7	25.0
Percent Commission	0.0	0.0	25.0	58.8	66.7	81.3
MIXED HARDWOODS (MH)						
Percent Correct	91.7	63.1	46.4	26.2	21.4	51.2
Percent Commission	6.1	28.4	37.1	36.1	56.1	21.8
CHAPARRAL (C)						
Percent Correct	85.4	41.6	45.8	45.8	29.2	29.2
Percent Commission	30.5	62.3	67.1	75.0	81.1	72.5
ANNUAL GRASSLAND (G)						
Percent Correct	89.3	80.0	76.0	69.3	44.0	65.3
Percent Commission	4.3	7.6	22.8	29.7	52.8	42.4
WATER BODIES (W)						
Percent Correct	100.0	93.3	90.0	83.3	83.3	90.0
Percent Commission	0.0	9.7	6.9	0.0	7.4	6.9
NON-VEGETATED AREAS (N)						
Percent Correct	75.0	75.0	58.3	62.5	54.2	16.7
Percent Commission	10.0	16.7	30.0	28.6	61.8	55.6

Figure 4.20 Interpretation results are expressed here as percent correct identification and percent commission error for the optically degraded aerial photography and the ERTS-1 image.

G

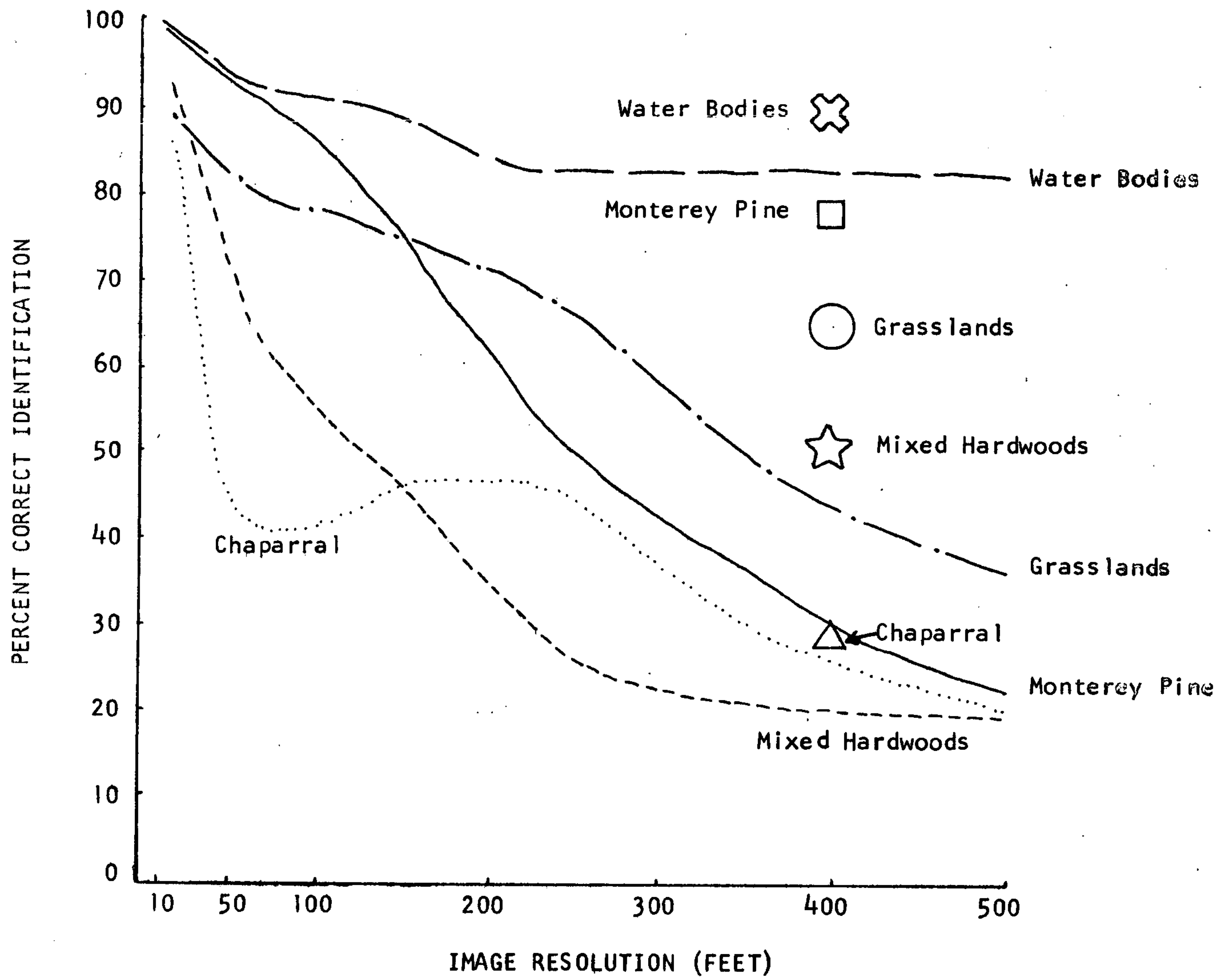


Figure 4.21 Interpretation results are presented here in graph form for all categories individually expressed as percent correct identification (data on eucalyptus and non-vegetated areas have been omitted due to an insufficient number of sample plots). The continuous lines represent percent correct identification on the degraded aerial photography. The symbols represent the percent correct as seen on the ERTS-1 image.

		GROUND DATA				TOT. SEEN BY P.I.	COM. ERROR	PERCENT COM.
		WV	G	W	N			
PHOTO INTERPRETER RESULTS	WV	**147**	23		7	177	30	16.9
	G	21	**49**	3	12	85	36	42.4
	W	1		**27**	1	29	2	6.9
	N	2	3		**4**	9	5	55.6
TOTAL PLOTS		171	75	30	24			
OMISSION		24	26	3	20			
PERCENT CORRECT		86.0	65.3	90.0	16.7			

Figure 4.22 Cumulative interpretation results for three interpreters are shown here. The numbers in the body of the box array of results indicate the total number of points identified by all interpreters. The numbers in the bold-faced diagonal row indicate the number of points identified correctly. Note that WV = woody vegetation, G = grassland, W = water, and N = non-vegetated.

CATEGORY	IMAGE RESOLUTION (FEET)					ERTS-1
	5-10	50-100	100-200	200-300	300-500	
<u>WOODY VEGETATION</u> (MP, E, MH and C)						
Percent Correct	98.8	98.2	93.6	91.2	80.11	86.0
Percent Commission	4.4	7.7	9.6	13.9	19.4	16.9
<u>GRASSLAND</u> (G)						
Percent Correct	89.3	80.0	76.0	69.3	44.0	65.3
Percent Commission	4.3	7.7	23.0	29.7	52.2	42.4
<u>WATER BODIES</u> (W)						
Percent Correct	100.0	93.3	90.0	83.3	83.3	90.0
Percent Commission	0.0	9.7	6.9	0.0	7.4	6.9

Figure 4.23 Interpretation results are expressed here as percent correct identification and percent commission error (Monterey pine, eucalyptus, mixed hardwoods and chaparral combined into one category) for the optically degraded aerial photography and the ERTS-1 image.

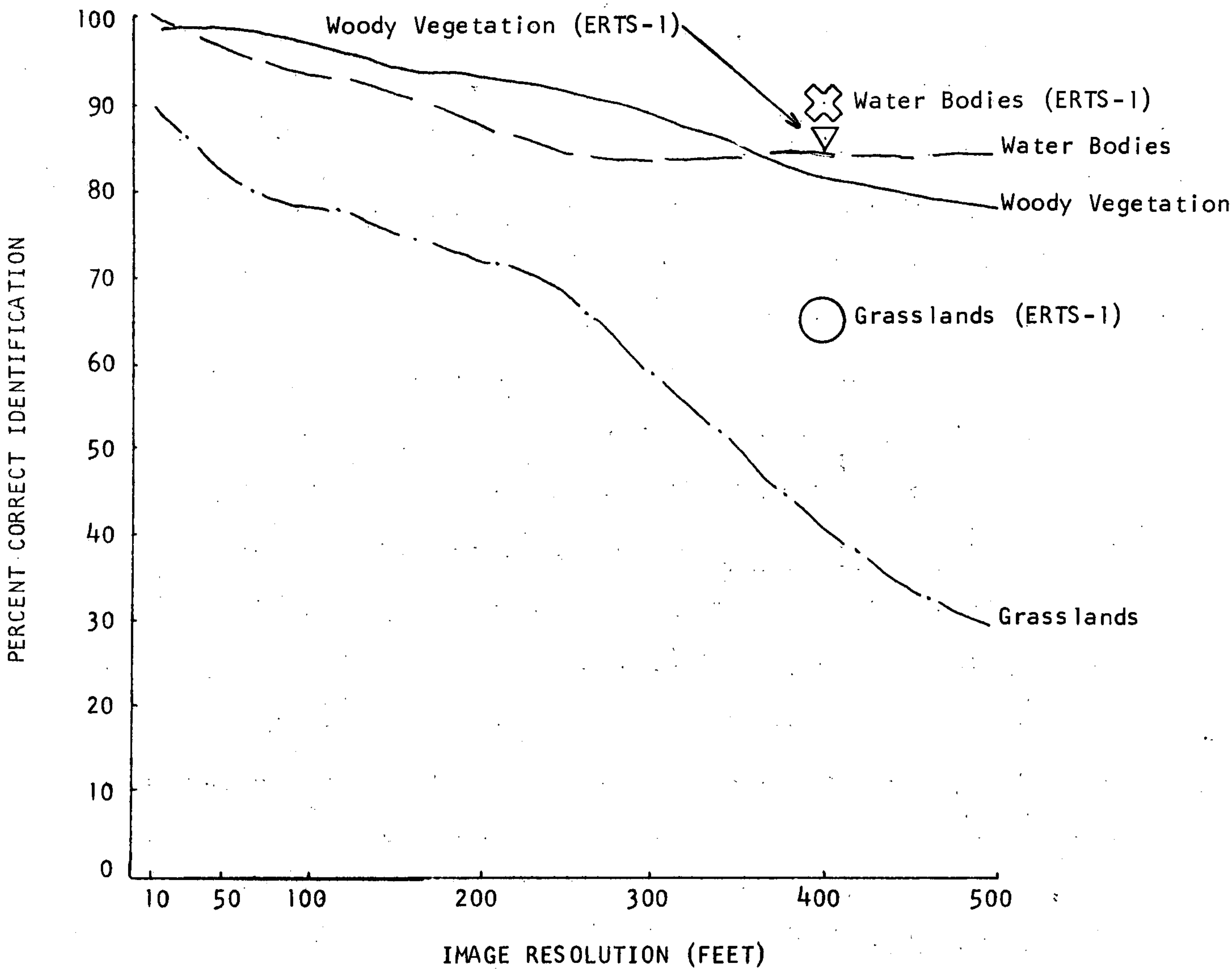


Figure 4.24 Interpretation results are presented here in graph form for woody vegetation, grassland and water expressed as percent correct identification. The continuous lines represent percent correct identification on the degraded aerial photography. The symbols represent the percent correct as seen on the ERTS-1 image.

committed plots divided by the total number of plots identified in that category and multiplied by 100 (in the example explained above for Monterey pine, 34 divided by 55).

A comparison between the results of interpretation done on the ERTS-1 image and that done on the degraded aerial photography can be seen in Figures 4.20, 4.21, 4.22, and 4.24. Note that all cover types were readily identified on the high resolution photography (5-10 feet ground resolvable distance), but that when image resolution dropped below about 50 feet many of the woody vegetation types were difficult to discriminate. For this geographic region of California, it was predicted in this earlier study using simulated data that identification accuracy would drop below 50 percent for nearly all types when image resolution was below 300 feet -- and identification accuracy would not be significantly improved until a resolution level of about 50 feet was reached. The analysis of the ERTS-1 image supports these earlier conclusions even though identification accuracies were generally higher using the ERTS-1 image than was predicted. For example, improvements were noted with the ERTS-1 imagery over <u>all</u> examples of the degraded imagery for identifying Monterey pine.

In general, on both the ERTS-1 image and the low resolution degraded photos, differentiation between various types of woody vegetation (i.e., Monterey pine, mixed hardwoods, eucalyptus and chaparral) was difficult. The data in Figure 4.19 shows that most of the errors in these four categories occured when they were confused with one another. Figures 4.22, 4.23 and 4.24 show improved results when these four categores are combined into one category, woody vegetation -- WV. The higher percent correct and lowered percent commission error for woody vegetation indicates the in-class confusion.

Commission errors involving grasslands classified as Woody Vegetation on the ERTS-1 image, are partly explained by the "bleeding" of the red colored vegetation into the yellow colored grassland areas. With the interpreters identifying discrete points rather than delineating area, this edge bleeding contributed to commission errors of grassland to woody vegetation. Likewise, the low percent correct in the non-vegetation category is attributable to several factors: (1) sprayed strands of chaparral were considered to be non-vegetated when ground truth was being established, but were usually identified as chaparral (low infrared reflectance in these areas as in the grasslands led to the confusion), (2) highway areas were not resolvable on the ERTS-1 image, and (3) bare soil areas appeared similar to grasslands.

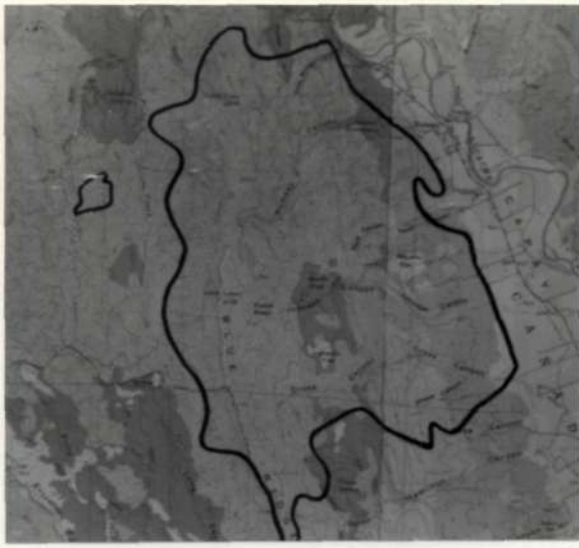
In summary, this preliminary study has shown that within a chaparral-hardwood-grassland type, one could expect that a skilled image analyst could delineate and identify on ERTS-1 imagery woody vegetation and water bodies with better than 86 percent accuracy. Classification accuracy for grasslands was considered to be low (65 percent), but one would expect better results with a placement of points away from boundary conditions. Consequently, the ERTS-1 image serves well where a user requires classification into major vegetation types; further, it is useful as a stage in a sub-sampling of stratification scheme where more refined imagery and ground data could then be obtained of areas delineated on the ERTS-1 imagery.

4.2.4 Post Fire Mapping

a. Methods and Procedures

In California, the State Division of Forestry is required to complete and file a fire map with the fire report to the District Office within 10 days of suppression (within 30 days to the State office). At present these maps are made by individuals walking or driving the fire perimeter while drawing boundaries on a topographic map sheet. In the case of very large fires, low flying aircraft or helicopters are employed while an individual draws boundaries by hand directly on a map sheet. These maps typically appear as shown in Figure 4.24, and are used almost exclusively for determination of location and acreage burned. This information is needed to establish the proportionate cost of suppression to be charged a cooperating agency when federal lands are burned during a natural fire (e.g., the Pocket Gulch fire, shown in Figure 4.25 was approximately half on Bureau of Land Management land). In the case of incendiary fires, an acreage estimate is needed to determine the amount of damage (which is added to suppression costs) so that convicted arsonists can be properly assessed and penalized (e.g., the Fiske Creek fire, also shown in Figure 4.25, was set, and the suspect's trial is currently pending).

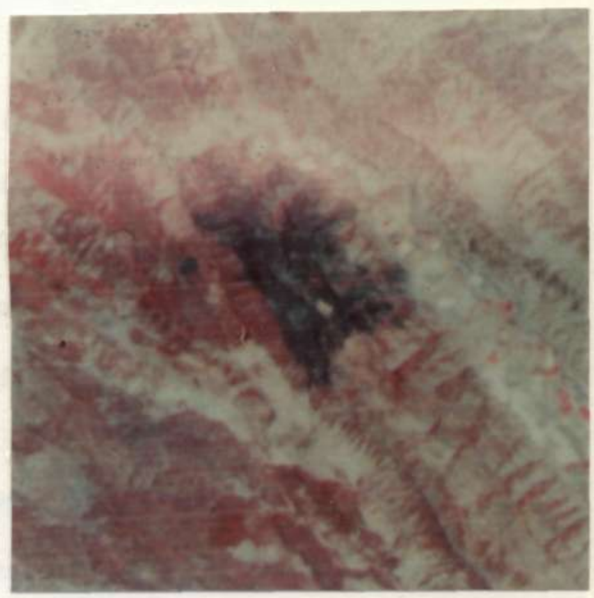
Perimeter delineations of the Pocket Gulch and Fiske Creek fires were made from an ERTS-1 MSS band 7, 9 x 9 inch transparency, acquired on July 27, 1972 (see Figure 4.25-C) approximately 10 days after



A. (Scale = 1:125,000)

C. (Scale = 1:110,000)

B. (Scale = 1:780,000)



D. (Scale - 1:270,000)

Figure 4.25

A. California Division of Forestry (CDF) map of Fiske Creeke (left) and Pocket Gulch (right) burns. CDF estimates of area burned were 60 acres and 10,340 acres respectively.

B. Portion of ERTS-1 MSS band 7 image taken on July 27, 1972. Enlargement of this image was used to create map in C.

C. Map of Fiske Creek and Pocket Gulch burns prepared by the Forestry Remote Sensing Laboratory from a single band black-and-white ERTS-1 image, as shown in B. Perimeter detail and information about damage levels within the perimeter are increased here relative to the CDF map in A.

D. Multiband color composite ERTS-1 image showing the two fires. Even more information appears extractible than was possible with a black-and-white single band image.

suppression of both fires. This simplified map was made using the Forestry Remote Sensing Laboratory scanning microdensitometer and computer capabilities for the purpose of comparing results and costs with the techniques currently used by the California Division of Forestry (CDF).

b. Results and Discussion

Figure 4.25-C, minus the interior delineations, is the equivalent of the CDF map, but made by the use of the ERTS-1 image and the FRSL computer system. The CDF and ERTS-1 maps differ significantly. Estimates of the fire areas were 10,340 and 13,340 respectively. The CDF spent approximately 4 to 8 hours (including flying the fire to draw the map, plus time to use a dot grid for area estimation), or about $1,000 to map the Pocket Gulch burn. The Forestry Remote Sensing Laboratory spent about 25 minutes (after the image was in hand) or about $50 to map the same burn. Low altitude oblique aerial photography confirms that the FRSL map and acreage estimate are more accurate than those prepared by the CDF.

More significant than the improved mapping in simplified form are the additional capabilities provided by ERTS-1 to map burn interiors in detail and also to monitor burned areas over time to evaluate revegetation progress. Figure 4.25-C shows areas of low to no damage within the Pocket Gulch perimeter. This type of map aids in more accurate damage assessment, better planning for salvage logging in timbered areas, improved immediate post-fire revegetation programs (where speed is essential to insure that aerially applied seed get through loose ashes before a rain, which would create both an unfavorable seed bed and highly visible targets for seed eating birds and animals), and rapid post-fire fuel hazard evaluation.

Figure 4.25-D illustrates the ease with which burned areas can be identified, boundaries delineated and various levels of damage discerned on an ERTS-1 false color composite. The small Fiske Creek fire -- only 60 acres by CDF estimates -- was readily seen even on black-and-white ERTS-1 imagery at the original scale.

The post-fire mapping of burned wildland areas is important for many reasons, and tens of thousands of these fires occur annually across the United States. Consequently, based on these preliminary results, it appears that <u>the use of sequentially procured ERTS-1 imagery, rather than conventional mapping procedures, can provide superior post fire maps, at more frequent intervals and with greatly reduced man-power requirements and costs</u>.

4.3 CONCLUSIONS

It is much too early to reach definitive conclusions regarding the feasibility of using ERTS-1 for detecting, inventorying and monitoring wildland resource features and conditions. However, the preliminary results reported upon above have been surprisingly good. There appears to be every indication that many kinds of <u>regional</u> resource information can be obtained more quickly, more reliably and at lower costs through the use of ERTS-1 imagery in comparison to conventional data gathering techniques. Likewise, <u>intensive area</u>

resource information, such as forest land classification, major vegetation type identification and post fire maps, can be easily and accurately obtained from ERTS-1 imagery by applying manual and/or automatic data extraction techniques which are currently operational. It must be remembered that (1) the case studies reported upon herein were done with the aid of one of the very first ERTS-1 images, taken in July over California, and (2) the unique characteristics of ERTS-1 lie in its synoptic view, sequential capabilities. Consequently one can expect that as ERTS-1 continues to procure high quality imagery on an 18-day cycle the relatively high accuracy and low cost figures associated with each study done to date will be improved -- and results derived from other experiments currently in progress (e.g., land use mapping and change detection in the north coast region, detection of offshore kelp beds, snow mapping, etc.) will be equally as impressive.

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DATE September 30, 1972

PRINCIPAL INVESTIGATOR R. N. Colwell

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100318175-M-B (San Pablo Res. study)	X			
100318175-5	X	X		
100318175-M-B (Fire Mapping study)	X	X		
100218125-4	X			
100218125-5	X			
100218125-7	X			
100218125-M-B	X			
100318173-M-B (Davis Lake)	X			
100218125-M-D (Davis Lake)	X			
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Chapter 5

ANALYSIS OF RIVER MEANDERS FROM ERTS-1 IMAGERY (UN644)

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Because of the unavailability of ERTS-1 data to these investigators, little progress was made during the period covered by this report in using remote sensing techniques to measure those characteristics of river meander patterns which indicate meander stability and stream discharge rate. It is recognized that such information can be very useful in developing and maintaining river control systems that are based on levees, check dams and diversion areas. In those parts of the world known as "developing areas" such information also can be valuable at the time when preliminary regional plans are being formulated.

While looking forward to the availability of ERTS-1 imagery, much of our study under the NASA Remote Sensing grant has recently been concentrated on establishing a possible correlation between the stream power spectrum (based primarily on an analysis of river meander directions and radii of curvature) and the stream discharge frequency distribution. As a result of this work we have now completed our analysis of the Feather River test areas and have established the procedures for generating the "stream discharge probability density functions" and the "meander power spectra" for other rivers.

The approach being used involves the digitization of river meander patterns from aerial photography (and eventually from ERTS-1 imagery) by means of photoelectric optical scanning. A continuous digitized record of the meander pattern for each bank of the river is thus obtained. As a result a set of data points (each having known X and Y coordinates) is developed at equally spaced intervals along the course of the river. For example, a 23-mile stretch of the Feather River has been so digitized recently by our group and subsequently analyzed to determine the wavelengths and spectral peaks of the meanders.

Having developed the procedures for generating the meander power spectra and the discharge probability density functions for rivers, we are now seeking to establish a correlation between these two functions as we conduct similar studies on a large number of rivers. We have obtained the hydrologic data on thirty river reaches from the Water Resources Division of the U.S. Department of Interior and the corresponding aerial photography and radar imagery from NASA and other sources. We currently are engaged in processing the data for these reaches in order to demonstrate quantitatively both the potential uses and limitations of our correlation study. Obviously the next step will be to incorporate these findings with the findings which we soon expect to achieve by tracing these same river reaches on ERTS-1 imagery.

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Chapter 6

USE OF ERTS-A DATA TO ASSESS AND MONITOR CHANGE IN THE WEST SIDE OF THE SAN JOAQUIN VALLEY AND CENTRAL COASTAL ZONE OF CALIFORNIA (UN070)

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Department of Geography, Santa Barbara Campus

The Geography Remote Sensing Unit (GRSU) at the University of California, Santa Barbara is responsible for investigations with ERTS-1 data in the Central Coastal Zone and West Side of the San Joaquin Valley. The nature of the investigative effort involves the inventory, monitoring, and assessment of the natural and cultural resources of the two areas. Land use, agriculture, vegetation, land forms, geology, and hydrology are the principal subjects for attention. These parameters are the key indicators of the dynamically changing character of the two areas. Monitoring of these parameters with ERTS-1 data will provide the information needed by federal, state, county, and local agencies to assess change-related phenomena and plan for management and development.

In conducting these investigations, close cooperation is being maintained with various agencies to define information requirements and establish mechanisms for information flow. Among the groups already cooperating are the Department of Water Resources, Division of Highways, Farm Advisors (Santa Barbara and Kings County), and the

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Kern County Water Agency. In the Coastal Zone, GRSU is cooperating with the Forestry Remote Sensing Laboratory (U.C. Berkeley) and the Geography Department at U.C. Riverside. The three groups are working in concert to develop classification schemes that are applicable along the entire California coastline. These activities will lead to the development of a relatively uniform Coastal Zone data base from ERTS-1 imagery.

In preparation for receipt of ERTS-1 data, considerable effort was placed on establishing a solid data base for the Central Coastal Zone. Detailed classification systems were devised for the resource parameters of interest, and maps were prepared from existing RB57 color infrared photography imaged in April, 1971 (NASA Mission 164). The data base is being used to evaluate the information content of ERTS-1 imagery. As continued ERTS-1 data is received, the classification systems will be modified to make them compatible with the information content of ERTS-1 imagery. A solid data base already exists for the West Side of the San Joaquin Valley as a result of previous research by GRSU, and it will be used in the same fashion as the Central Coastal Zone data base.

The balance of this report, sections 6.1-6.6 are concerned with a preliminary evaluation of ERTS-1 data already received. Sections 6.1-6.3 deal with (respectively) land use, agriculture (crop identification), and vegetation mapping. Discussion centers on problems encountered, accomplishments during this reporting period, and detailed results. Section 6.6 is a summary of results from the preceding sections. ERTS Image Descriptor Forms are also included. The key words used to describe the itemized ERTS-1 images represent a preliminary evaluation of information content by GRSU personnel.

6.1 PRELIMINARY EVALUATION OF ERTS-1 IMAGERY - LAND USE

Preliminary analysis of land use features from ERTS-1 imagery concentrated on determining the feasibility of identifying and mapping various cultural patterns. The most important of these were: (1) urban concentrations (including location and extent); (2) transportation routes; and, (3) agricultural field boundaries. The test region chosen was located on frame # 1002-18140 and divided into four areas. The areas ranged from southeast of Morro Bay (approximately at Avila Beach), north along the coast past Monterey (to the mouth of the Salinas River), then inland to Salinas, southeast to the vicinity of Paso Robles, and finally south to San Luis Obispo (see Figure 6.1). The synoptic view afforded by the imagery presented an opportunity to study a sampling of the hetereogeneous land use patterns in central coastal California. The imagery evaluated included the four Multispectral Scanner (MSS) Bands (Channels 4-7), using 9.5" positive transparencies.

While this land use study is still in the intial stages, several conclusions/observations may be made concerning: (1) problems encountered; (2) accomplishments during the initial period; (3) an overall evaluation of the four bands; and (4) plans for future research.

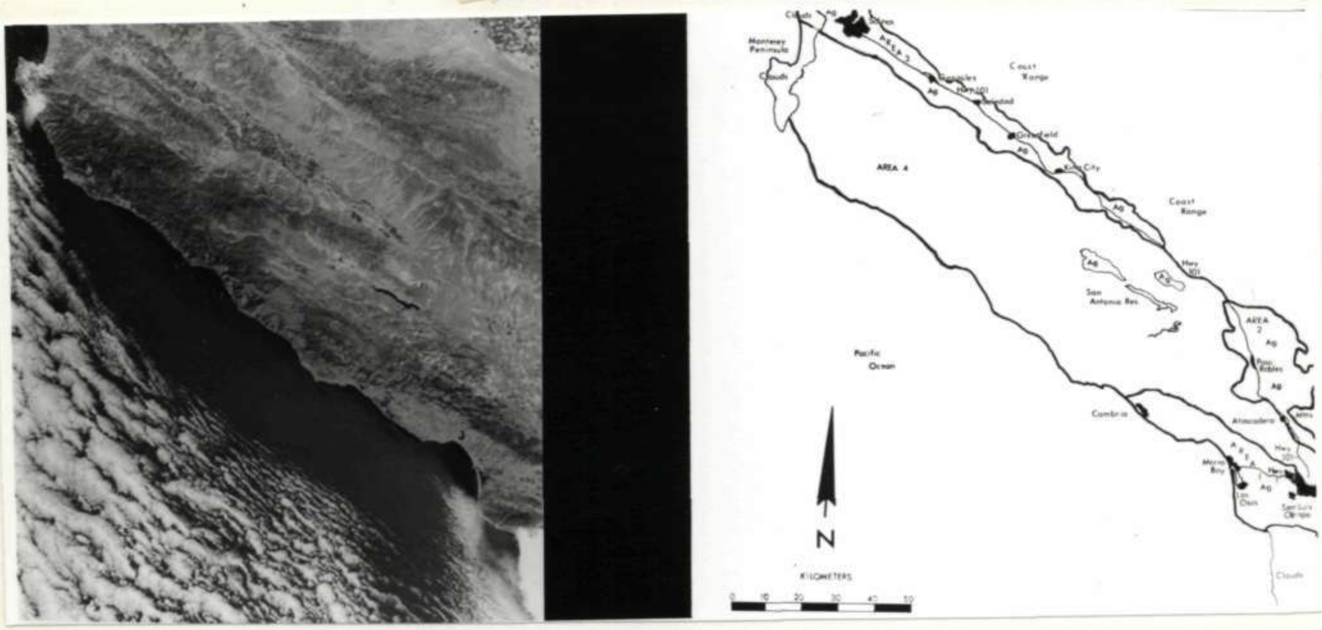

Figure 6.1 General Land Use Map (right) drawn from ERTS-1 image #1002-181405 (left) and depicting: a) the four areas analyzed in the preliminary study; and, b) the primary urban, transportation and Agricultural (symbol-Ag) features. In addition, several features not visible in all MSS bands of image #1002-18140 (e.g., the urban areas of Atascadero and Paso Robles) have been included for ease of reference.

6.1.1 Initial Problems Encountered

While the major interpretation difficulties centered around the resolution levels of the various MSS bands, several other problems were encountered. For instance, where tone and/or texture signatures exhibited low contrast ratios, it was very difficult to discern urban from non-urban features. This was especially evident in Area 1 where, except for a slightly lighter tone and a more mottled texture, the cities of San Luis Obispo, Morro Bay, Cambria and Los Osos (located in the former) tended to blend in with the subtle tones of the surrounding grassland/rangeland. In Area 2, Paso Robles and Atascadero were similarly difficult to accurately locate. A further problem in locating urban concentrations in these two areas was the poor response of highways (both U.S. 1 and 101). This was in marked contrast to Area 3, which includes the Salinas Valley (an area of extensive agricultural production). Here, the lighter, usually mottled expression of urban areas contrasted sharply with the darker tone and more continuous texture of the surrounding "regularly" patterned fields. This resulted in a more precise identification of Salinas (especially on MSS Bands 4 and 5), while four smaller centers (Greenfield, Gonzales, King City and Soledad) were also visible. In addition to characteristic shapes of urban boundaries, the linear signature and continuous tone of U.S. 101 (the major artery through the valley) reduced urban "search" time considerably.

6.1.2 Accomplishments During the Initial Period

During this period, an evaluation of the four MSS bands was completed for the test region (see Tables 6.1-6.3) by specifically examining the signatures of the urban, transportation, and agriculture land use categories on each band. Urban concentrations and transportation routes were located by scanning the images with a 10x magnifier to identify the typical tone/texture responses of each, and then the gross outlines and/or linear patterns interpreted from the imagery were compared with U.S.D.C. Coast and Geodetic Survey Sectional Aeronautical Charts for verification purposes.

While Area 3 presented few problems in identification, Areas 1 and 2 were more difficult.[1] Area 1 required intensive examination before certain key tones and textures became obvious to the interpreters, enabling them to locate urban features. However, owing to the lack of sufficient contrast between tones and textures, Area 2 continued to represent a definite interpretation problem.

Agricultural signatures in all four areas were generally quite satisfactory, with fields as small as 40 acres visible. Furthermore, tonal differences in field plots (both on the macro and micro level) were noted and their significance is being analyzed. Finally, general land use maps for the region as a whole are in the process of completion, while more specific maps of selected test sites are being

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[1]Area 4 is largely ignored in this report as the more significant cultural land use centers were obscured by clouds.

TABLE 6.1 EVALUATION OF MSS BANDS (CHANNELS) 4 - 7 (URBAN CONCENTRATIONS)

BAND 4	BAND 5	BAND 6	BAND 7
Area 1 - Poor to Fair. San Luis Obispo tends to blend with surrounding grassland - lighter tone and mottled texture are evident but not obvious. Along U.S. 1 between San Luis Obispo and Morro Bay, a prison and army camp are visible (white to light grey against medium grey). Cambria is visible as street patterns stand out.	Area 1 - Poor to Fair. San Luis Obispo very evident as mottled texture contrasts strongly with texture of surrounding land. Also, Los Osos, south of Morro Bay is visible owing to lighter color and apparent street patterns. Additionally, Cambria, in a stand of conifers (dark grey) is well defined (light grey).	Area 1 - Poor. Urban blends with surrounding grassland. Morro Bay poorly defined. Los Osos and Cambria not located.	Area 1 - Poor to Fair. In San Luis Obispo, CBD displays medium grey signature, which contrasts well with light grey of radiating urban area. Morro Bay and Los Osos show fair tonal differentiation, as their light grey contrasts with darker perimeters. However, in all of these, problem of urban/non-urban merging remains.
Area 2 - Very poor tonal contrast.	Area 2 - Very poor.	Area 2 - Very poor.	Area 2 - Very poor.
Area 3 - Good to excellent. All five cities are well defined. (Vary from white to light grey) against dark background.	Area 3 - Fair to Good. Urban response not as clear as Band 4. While Greenfield and Gonzales are identifiable by shape and tone/texture (white-light grey and slight mottling), Soledad and King City blend with surrounding agricultural land. Salinas easily located by white signature of CBD. However, boundaries tend to fade at interface with non-urban.	Area 3 - Poor to Fair. None of 4 smaller cities south of Salinas defined. Salinas, however, has strong signature.	Area 3 - Poor to Fair. Four smaller cities again are undifferentiable, owing to lack of tonal contrast. Salinas, with light to medium grey tone and mottled texture, also shows some street patterning. Border between urban and non-urban is well defined owing to tonal differences.
Area 4 - Obscured by clouds.	Area 4 - Obscured by clouds.	Area 4 - Obscured by clouds.	Area 4 - Obscured by clouds.

TABLE 6.2 EVALUATION OF MSS BANDS (CHANNELS) 4 - 7 (TRANSPORTATION LINKS)

CATEGORY	BAND 4	BAND 5	BAND 6	BAND 7
U.S. 101	Poor to Good. White linear signature appears best against dark grey or near black, especially in agricultural region of Salinas Valley and Mountain region north of San Luis Obispo. Tended to fade and blend with light grey in San Luis Obispo area and disappear into Salinas.	Poor to Good. Tended toward a light grey response. Not evident in San Luis Obispo Area nor within Salinas. Also, tended to blend into Salinas River signature in Area 2.	Very Poor to Poor. Very poor except in the Salinas Valley from Salinas-Soledad. Even here the grey signature tends to merge with other greys around it. Not visible at all from Soledad to San Luis Obispo.	Poor to Good. Good through the Salinas Valley-presents a dark tone in contrast to lighter agricultural areas. Response fairly good south of King City but again fades. Visible through mountains north of San Luis Obispo, but fades in San Luis Obispo.
U.S. 1	Poor. Tends to blend with light grey tones of San Luis Obispo-Morro Bay. Invisible along most of the coast from Morro Bay northward.	Poor to Fair. Along coast, portions are visible. Bend at Cambria especially apparent as are portions along raised sea platform to the north between Monterey-Cambria.	Very Poor.	Poor to Excellent. Excellent through Morro Bay proper. Fair from Morro-Bay-San Luis Obispo, through grassland. Not well defined along rest of coast.
Other Roads	Poor, except for Business 101 through Greenfield and Gonzales.	Poor to Fair. Possible to see roads separating fields in Salinas Valley.	Very Poor.	Fair. Street patterns in Salinas are visible.
Airports	None visible.	Poor. Airport at Salinas gives faint dark grey image on Southeast corner of city. Runway pattern fair.	Good - runways well defined.	Good. Similar to Band 6.

TABLE 6.3 EVALUATION OF MSS BANDS (CHANNELS) 4 - 7 (AGRICULTURE)

BAND 4	BAND 5	BAND 6	BAND 7
Area 1 - Field borders are poorly defined.	Area 1 - field definition is fair. Tones vary from white through greys into near black.	Area 1 - field borders are poorly defined.	Area 1 - same as Band 6.
Area 2 - field borders are fair in definition.	Area 2 - same as Band 4.	Area 2 - same as Band 4.	Area 2 - field definition is fair to good.
Area 3 - field borders are fair in definition.	Area 3 - field definition is good to excellent, with excellent tonal contrasts.	Area 3 - field definition is poor to good. Tends to be "washed out" in appearance.	Area 3 - field definition is good to excellent as contrast is very sharp.
Area 4 - field borders are fair in definition.	Area 4 - field definition is fair to good.	Area 4 - field definition is fair.	Area 4 - same as Band 6.

planned (utilizing photographic enlargements).

6.1.3 Future Research

Further research on at least two broad fronts will be developed: (1) the use of sequential ERTS-1 imagery for urban growth/planning analysis; and, (2) the use of ERTS-1 imagery as an agricultural indicator. As the techniques of urban identification are refined, it should be possible to note changes in the urban landscape (e.g., growth of boundaries owing to new housing projects on the fringes and/or the phenomena of "leapfrog" development), the effects of new transportation routes (especially highways), and other urban change indicators. The use of the synoptic view should aid local/county/state planners in determining the overall impact of projects both at the local and regional levels.

Even more dynamic than urban change is the potential use of ERTS-1 imagery as a means of evaluating agricultural resources. By combining the availability of sequential ERTS-1 coverage at eighteen day intervals with tonal/textural responses of crops, it may be possible to establish several important agricultural indicators. Once the tonal/textural responses of crop patterns/types have been ground truthed and matched to known imagery, it may be feasible to estimate potential crop yields, establish crop calendars, detect plant disease and determine irrigation practices over a wide area.

Additional research will be conducted to determine a suitable land use classification system adapted to the capabilities of ERTS-1 imagery. Also, future studies will include the coastal areas of Santa Barbara and Ventura counties as ERTS-1 imagery of these becomes available.

6.2 CROP IDENTIFICATION

A preliminary evaluation of the potential use of ERTS-1 data for crop identification has been conducted using MSS color composite 1002-18134. Initial results tend to indicate that images from the ERTS-1 platform can be used to differentiate crops in a diversified agricultural area.

The study area for this analysis was a fifty-six square mile block of farmland located immediately west of Mendota, in the Central San Joaquin Valley, California. The agriculture in this sample area is representative of the complex and varied nature of farming in the San Joaquin Valley. For example, crops grown within the test area boundaries commonly include alfalfa, barley, cotton, three varieties of melons, safflower, sugar beets, and tomatoes. Furthermore, on a somewhat irregular basis, asparagus, carrots, and garlic may also appear in this region.

6.2.1 Identification Procedures

The procedure for this evaluation involved a ten times enlargement of the color composite print from the print scale. The enlargement took the form of a positive transparency which could be projected for the purpose of identifying crops at a larger scale. It should be emphasized that the resolution of this enlargement was somewhat poorer than the original because the positive transparency was made from a print. However, most individual fields are easily discerned. Since field sizes are usually no smaller than 80 acres, the recognition of any particular field is a relatively simple task. In addition, precise definition is not actually a prerequisite from the imagery since the actual identification or differentiation of crops is made on the basis of certain color or tonal variations between fields. In fact, field boundaries are often recognizable as a result of tonal contrasts, even though resolution is insufficient to discern any existing cultural boundary such as a road. Basically, these tonal variations occur as result of differences in crop type and field conditions.

In addition, ground truth for the test area was collected coincident with the ERTS-1 overflight of July 25. From this data it was determined that alfalfa, bare soil, cotton, melons, sugar beets, and tomatoes were present in the test area in sufficient acreages to attempt identification.

In order to obtain a quantitative measurement of interpretation accuracy, a photo interpretation test was devised and administered to two highly experienced interpreters. The test itself required that the interpreters study a selected transect which crossed the area under investigation. The individual boundaries of each field along the course of the transect were marked and the category of crop or the field condition were noted. The transect was chosen because there were one or more representative fields of each crop or field condition category along its path. Apart from specifying the location of the testing area, this was the only information that was supplied to the interpreters. Actual testing was conducted directly on overlays covering the projected 10 times enlargements. The interpreters were required to categorize each individual field in the 56 square mile test area by comparing tonal contrasts with "known" fields along the transect. A few fields contained crops which did not appear along the transect, and such fields were eliminated from consideration in the testing. For example, within the study area there were 640 acres of asparagus. These fields were eliminated from the test during correction and, therefore, do not appear in the results.

6.2.2 Results

The test was corrected to determine: (1) the percent correct identifications for each category -- found by dividing the number of correct responses (Cor) by the total of correct possibilities (PC) and multiplying the result by 100 ($\frac{Cor}{PC} \times 100 = \%\ Cor$); (2) percent omission errors (i.e., fields that were within the category but which the interpreter failed to identify correctly) -- found by subtracting the number of correct responses from the total possible correct (PC), and multiplying the result by 100 ($\frac{Om}{PC} \times 100 = \%\ Om$); and, (3) the percent commission errors (i.e., those fields which the interpreter incorrectly identified as belonging to the category under consideration -- found by dividing the total number of responses in that category, minus the correct responses (PE), into the total number of incorrect responses (Com) and multiplying that result by 100 ($\frac{Com}{PE}$ x 100 = % Com). The results of the test are summarized in Table 6.4. It should be noted that the complete study areas was divided into 160 acre sections, since this was, by far, the most common field size found to occur within the study area. Each 160 acre area was interpreted separately. As a result, the data is expressed in terms of the number of 160 acre plots within the test area or fractions thereof.

Preliminary examination shows the percentage of correct identifications in each category (with the exception of bare soil) to be quite low. However, the low percentage of correct identifications does not actually indicate that crop identification using ERTS-1 data would be impossible or even difficult.

Generally, the interpretation conducted for this evaluation was done on the basis of color and tonal contrasts between categories. Error occured when the particular tone or color signature of any one category overlapped with the signature of another category. For example, Table 6.4 shows alfalfa was incorrectly identified (omission error) the majority of the time. The misidentification of this crop primarily resulted from the varied tonal response alfalfa may have from one field to another. In the Southern San Joaquin Valley, alfalfa is a crop grown twelve months of the year and is harvested from seven to ten times during that period. Consequently, at any one date this crop would probably vary a great deal in tone signature from one field to another. Crop identification (omission and comission errors) involving cotton, melons, sugar beets, and tomatoes primarily resulted from the

TABLE 6.4 ACCURACY OF IDENTIFICATION OF SELECTED CROP AND FIELD CONDITIONS ON ERTS-1 IMAGERY.

Ground Truth Categorization of fields	Photo Interpreter Identification of Fields						actual number of fields in category	% correct identification	% commission error
	Alfalfa	Bare Soil	Cotton	Melons	Sugar Beets	Tomatoes			
Alfalfa	12.5	2	24.5	3	10	0.5	52.5	24	25
Bare Soil	0	26	0	1	0	0	27	97	.006
Cotton	6	0.5	32	5.5	3.5	1	48.5	66	11
Melons	0	0	5	2	0	0	7	28	.03
Sugar Beets	0	0	1	0	4	2	7	57	.02
Tomatoes	3	0	2	4	3.5	2.5	15	16	8

Total Number of Fields Interpreted 157.

lack of color or tone differences between categories. In the case of bare soil, 97 percent of the fields were identified correctly because the vegetated/nonvegetated contrast exhibited maximum tonal differentiation between categories. This finding is considered to be of major significance for future testing and research in crop identification on ERTS-1 imagery.

6.2.3 Problems and Future Research

It is important to note that this evaluation was conducted using ERTS-1 imagery taken on July 25, 1972. No other date was available. Consequently, this crop identification survey was, in essence, of a static rather than dynamic nature. Much of the information which will be gained from ERTS-1 comes from its ability to produce images which will enable researchers to monitor change on an 18 day basis. Using sequential imagery, a crop identification technique would become more dynamic. For example, certain phenological changes occur as plants grow, mature, and are harvested. These changes may be reflected in a variable signature for a crop as it progresses through its growth cycle. The problem encountered in this survey, because of the single date of imagery available (in the middle of the summer growth cycle) was that most of the crops exhibited overlapping or extremely similar signatures. It is improbable that this type of confusion will result when sequential imagery is used.

In addition, multidate photography would allow the determination of growing seasons -- further enhancing the ability of any particular crop to be identified. From this survey, we know that bare soil fields, which signal the beginning and the end of any growing season, can be accurately identified on the basis of tone or color contrast. By monitoring growing seasons and tone signatures on an 18 day basis, it is probable that ERTS-1 imagery can be used to provide accurate agricultural surveys. This concept will form the basis for continuing agricultural research in the San Joaquin Valley.

6.3 VEGETATION MAPPING

The evaluation of ERTS-1 imagery for purposes of vegetation mapping entailed five phases: (1) the formulation of a system for classifying the vegetation types found in the test area; (2) the acquisition of ground truth data in the form of data base vegetation maps; (3) familiarization with image characteristics of ERTS-1 imagery; and, (5) an evaluation of the information content of ERTS imagery. A description of the work accomplished with respect to these five phases is included in this section with phase 5, the evaluation, being broken down into an evaluation of the interpretability and information content of ERTS data for vegetation mapping purposes and problems encountered in the interpretation of ERTS imagery. A sixth section is included and will describe research which will be carried out during the next reporting period.

6.3.1 Formulation of a System of Vegetation Classification

Before a preliminary evaluation of the utility of ERTS imagery for vegetation mapping purposes could be performed, it was necessary to prepare a suitable vegetation classification scheme. Such a scheme should be designed so that it: (1) includes major plant communities along the California coastline; and, (2) is flexible enough so that it can be expanded or contracted for use with variable photographic scales and/or resolutions.

In order to prepare such a classification scheme, a thorough examination of literature on California natural vegetation was carried out. The resultant scheme was derived, for the most part, from five sources (California Parks and Recreation, 1971; Critchfield, 1971; Kuchler, 1964; Munz and Keck, 1970; and Nash, 1970). This scheme consists of a hierarchical classification of coastal California's natural vegetation and is divided into three basic levels (see Table 6.5). The first and most general level is divided into aquatic vegetation and terrestrial vegetation; the second level comprises major vegetation groups on a physiognomic basis (e.g., grassland, scrub vegetation, forest, etc.); and, the third level breaks down these general physiognomic classes into individual vegetation communities.

Symbols were developed for use on vegetation maps which indicate both the physiognomic and community affiliation of each vegetation type. The system is open-ended, thus making it feasible to add or subtract symbols depending upon the precision required for vegetation mapping.

The overall classification system and the symbols were tested on preliminary maps. Both the classification system and symbols used

TABLE 6.5 NATURAL VEGETATION CLASSIFICATION SYSTEM

Plant Category	Symbol
I. Aquatic	
A. Marine	M
1. Nearshore (kelp and seaweed)	Mn
2. Intertidal	Mi
B. Freshwater	Fw
C. Marsh	Ma
1. Salt Marsh	Ma_{sm}
2. Freshwater Marsh	Ma_{fm}
II Terrestrial	
A. Barren	Ba
B. Strand	Sr
C. Grassland	G
1. Coastal Prairie	Gcp
2. Valley Grassland	Gvg
3. Meadows (rare)	Gme
D. Woodland Savanna	Ws
E. Scrub	S
1. North Coast Shrub	Snc
2. Coastal Shrub	Sc_{sh}
3. Coastal Sagebrush (soft Chaparral)	Scs
4. Cut-over Forest	Scf
5. Chaparral (hard Chaparral)	Sc
6. Scrub-Hardwood	Shw

TABLE 6.5 (continued)

Plant Category	Symbol
F. Forest	F
1. Hardwood	Fhw
2. Mixed Evergreen	Fme
3. Coniferous	Fco
a. Redwood	Fco_{rw}
b. North Coast	Fco_{nc}
c. Douglas Fir	Fco_{df}
d. Pine Cypress	Fco_{pc}
G. Riparian	R

appear to be workable and describe the "reality" of the characteristic vegetation types mapped.

6.3.2 Acquisition of Ground Truth Data

The information content of any remote sensing imagery can only be effectively evaluated if an accurate data base either exists or is obtained for the area under consideration. With this in mind, data base maps of the natural coastal vegetation in the proposed ERTS-1 test area (from San Simeon Point, San Luis Obispo County to the Oxnard Plain, Ventura County) were prepared. The preparation of these maps entailed the use of 1:60,000 and 1:120,000 scale high-altitude color infrared photography taken in April, 1971. Stereo coverage was available in most cases and the overall quality of the imagery was excellent. The actual data base maps were constructed on cellulose acetate overlays. Site locations of representative plant communities were selected and ground truthed in order to evaluate interpretation accuracy. Herbarium specimens of dominant plant species within each community were also collected to relate physiognomic characteristics (e.g., leaf structure and plant geometry) to variations in tonal response apparent on the imagery.

6.3.3 Familiarization with ERTS-1 Imagery

A time period of approximately one week was allotted to the study of ERTS-1 imagery so as to familiarize the interpreters with its unique tonal, textural, and scale qualities. All seven (7) MSS and RBV bands and the Monterey Bay area bulk color composite were examined with the aim of selecting the most appropriate band for vegetation studies. The results indicated that, of the seven black-and-white bands, band 5 was most suitable.

Using both the color composite and band 5 (imaging in the red portion of the spectrum from .6-.7 microns), vegetation boundary delineations were drawn using cellulose acetate overlays. These maps were then compared with the 1:120,000 and 1:60,000 vegetation data base maps prepared from high altitude color infrared photography.

After comparing the ERTS-1 imagery with the conventional photography and vegetation data base maps, it was possible to determine relevant tonal ranges, textural characteristics, shapes, and locational parameters for each vegetation community under consideration. From these data, a descriptive interpretation key was prepared. (This key is shown in Table 6.6.) Using this key as a basis for interpretation, two complete vegetation maps were prepared from photographic enlargements of portions of the ERTS-1 image number 1002-18140 taken on July 25, 1972.

6.3.4 Interpretation and Preparation of Vegetation Maps

Two representative test areas on ERTS-1 image number 1002-18140 were selected for the preparation of vegetation maps. Five-time (5x) photographic enlargements were prepared of the test area (8 x 10 print size), so that the resultant scale was approximately 1:200,000. This format enabled the interpreters to delineate continuous vegetation

TABLE 6.6 VEGETATION INTERPRETATION KEYS

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Barren	Ba	white to light grey	continuous		In man-induced and naturally disturbed areas.	Mostly lacking or devoid of vegetation.
Coastal Strand	Sr	light grey to grey	continuous to streaked		Dunes and sandy beaches dispersed along entire coast with community variability from north to south.	Consists of low prostrate vegetation, often succulent woody perennials. Genera include; Atriplex, Franseria, Lupinus, and Abronia.
Coastal Salt Marsh	Ma_{sm}	dark grey to black	continuous		Coastal habitats, sea level to 10 feet. Most extensive on tidal flats and lagoons.	Lacking perennial grasses Mostly succulents, herbs or shrubs and prostrate vegetation. Characteristic genera include Salicornia, Suaeda, and Distichlis.
Coastal Sagebrush (Soft Chaparral)	Scs	Grey	mottled		Transverse, peninsula and South Coast Ranges to Baja, California. Mostly below 3,000 feet between the ocean and chapparal communities.	Occurring on dry and semi-rocky moderate to steep south and west facing slopes. Shrubs 1-5 feet in height with fasciculate leaves. Fairly continuous ground cover although less dense than chaparral. Characteristic genera include Salvia, Artemesia, Baccharis, and Eriogonum.

TABLE 6.6 (cont'd)

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Chaparral	Sc	dark grey to black	mottled to patchy		Coast Ranges from southern California to Mexico, notably in San Luis Obispo and Santa Barbara counties. Occurring in dry, rocky slopes and ridges often north facing on lower altitudes and south facing on higher altitudes to 6000 feet.	Pyrophytic and evergreen shrubs. Dense, broad-leaved, and sclerophyll vegetation, 3 to 15 feet in height. Occurring as a continuous, often impenetrable cover. Characteristic genera include; _Adenostoma_, _Coenothus_, and _Arctostaphylos_.
Grassland	G	light-grey	continuous		Low hot valleys of coast ranges on clay soils from sea level to 3000 feet.	Uncultivated grasses and low associated herbaceous plants. Characteristic genera include indigenous _Stipa_, _Poa_, and _Aristida_, and replacement genera including _Bromus_, _Avena_, _Festuca_.
Woodland-Savannah	WS	light-grey to grey	mottled to patchy		Occurring in areas of mergent grass and woodland from sea level to 6000 feet.	Open stands of broad-leaved trees and evergreen with intermittent grass and herbaceous vegetation. Refer to Forest Hardwood and Grassland.
Scrub-Hardwood	Shw	dark-grey to black	mottled		Refer to Hardwood Forest.	Open stands of broad-leaved trees with open spaces occupied by sagebrush, chaparral, and low herbaceous vegetation.
Forest Hardwood	Fhw	Black	continuous to mottled		Semi-rocky to clay soils on foothills and in valleys. Inner coast ranges from sea level to 4,000 feet.	Mixed or homogeneous stands of broad-leaved species 15 to 70 feet in height forming a closed or nearly closed canopy. Characteristic genera include: _Quercus_, _Pinus_, and _Umbel-_ [redacted]ari[redacted]

TABLE 6.6 (cont'd)

Classification	Symbol	Tone	Texture	Shape	Distribution	Community Characteristics
Forest-coniferous	Fco	black	mottled		Coastal ranges from sea level to 12,000 feet.	Dense stands of homogeneous or mixed coniferous trees ranging from 10 to over 100 feet in height. Closed or nearly closed canopy. Characteristic species include *Pinus muricata*, *P. Radiata*, and *Cupressus Sargentii*.
Riparian	R	dark grey to black	mottled to patchy	thin streamers, sometimes patchy	Species of trees and shrubs restricted to streambank environments from sea level to 6000 feet.	Broad leaved trees 10 to 70 feet in height forming a dense crown cover. Understory consisting of low shrub and herbaceous growth (generally phreatophytic) along stream course. Characteristic genera include: *Platanus*, *Acer*, *Alnus*, *Populus*, and *Salix*.
Agriculture	Ag	dark grey to black	continuous	rectangular	Coastal and montane regions.	Regularly cut hay lands, cultivated and irrigated fields.
Water Body	WB	black	continuous		marine and terrestrial	

units, often less than .25 square kilometers in areal extent.

Utilizing the information contained in the photo-interpretation key in Table 6.6, plus an _a priori_ knowledge of the vegetation types that are generally found in these areas, complete vegetation maps for each of the two test areas were prepared. The resultant maps and the two enlarged images which were used in the interpretation are shown in Figures 6.2 and 6.3

6.4 EVALUATION

6.4.1 Interpretability and Information Content of ERTS Data

Vegetation communities, present in the two test areas and mapped from the ERTS-1 imagery, included barren ground (Ba), coastal strand (Sr), coastal salt marsh (Masm), coastal sagebrush (Scs), chaparral (Sc), grassland (G), woodland-savannah (WS), scrub-hardwood (Shw), hardwood forest (Fhw), coniferous forest (Fco), and riparian (R), agriculture (A), urban (U), and waterbodies (Wb) were also present and mapped in order to differentiate them from natural vegetation communities.

On 1:120,000 color infrared photography, it was possible to correctly identify all of these categories 100 percent of the time on the basis of: (1) hue or color differences; (2) textural differences; (3) shape; and, (4) location. On the ERTS-1 imagery, however, correct identification and delineation of each community was more difficult owing to: (1) decreased spatial resolution; (2) reliance on only gray-scale tonal differences on the black-and-white image; i.e., the loss

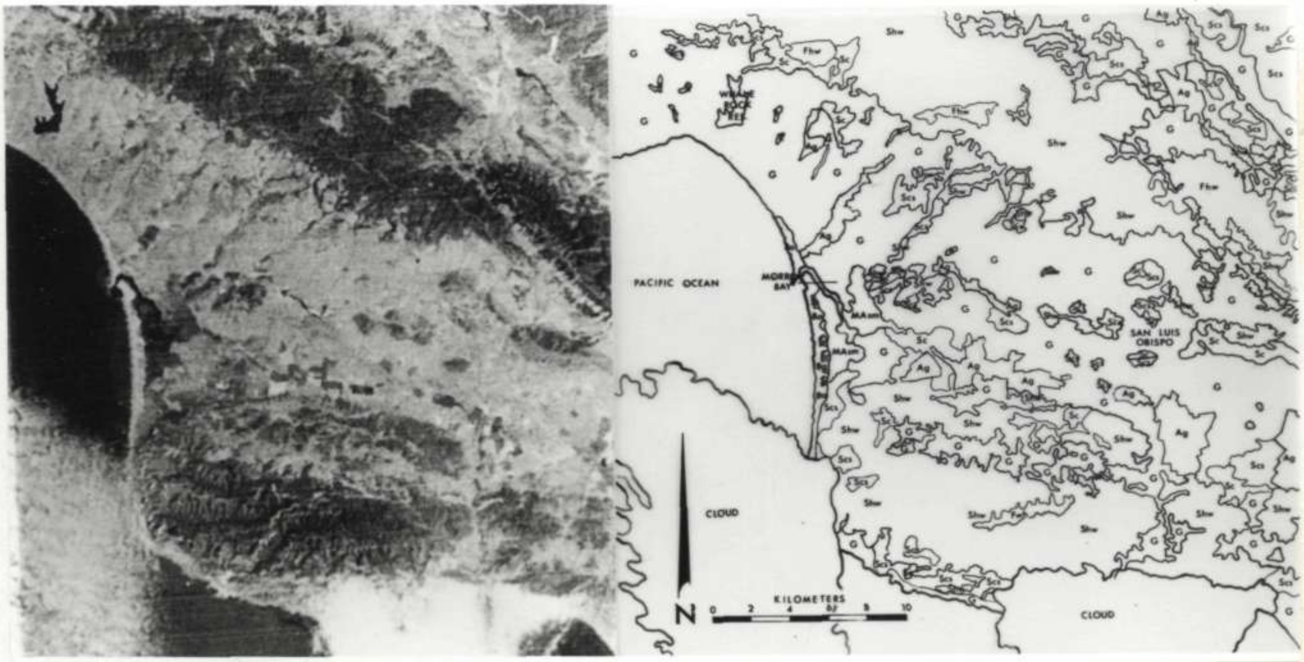

Figure 6.2 Copy of five times (5x) enlargement of a portion of ERTS-1 image 1002-181405 (.6-.7 micrometers), and adjacent vegetation community map prepared using this image. The symbols represent the following communities or terrain types: Ba (Barren), Sr (Coastal strand), Masm (Coastal salt marsh), Scs (Coastal sage), Sc (Chaparral), G (grassland), WS (woodland savannah), Shw (scrub-hardwood), Fhw (hardwood Forest), Fco (coniferous forest), R (riparian vegetation), A (agriculture), U (urban), and WB (waterbodies). The area imaged on this photo is approximately 1200 square kilometers centered on the city of San Luis Obispo, California (original scale of enlargement used for mapping purposes was approximately 1:200,000).

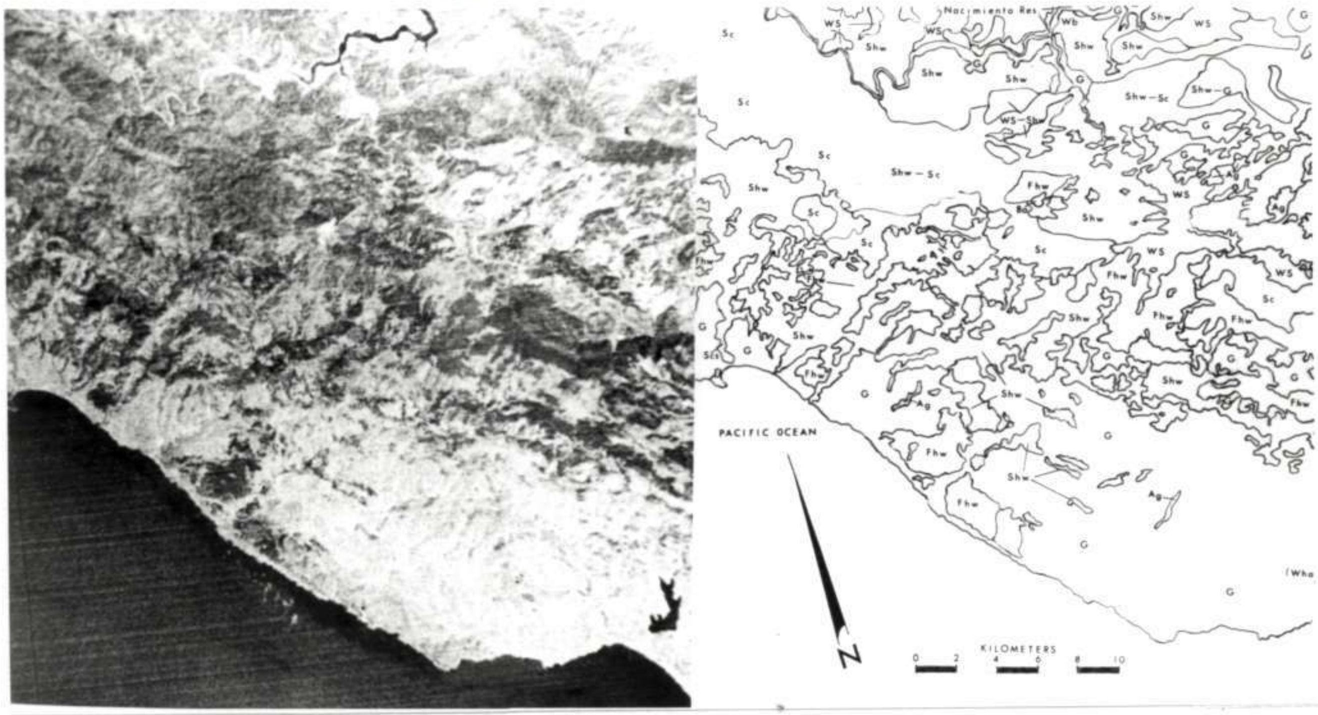

Figure 6.3 Copy of a five times (5x) enlargement of a portion of ERTS-1 image 1002-181405 (.6-.7 micrometers), and adjacent vegetation community map prepared using this image. Symbols representing plant communities are indicated on the map. Two symbols are sometimes used in conjunction to represent areas of transition or intermixing, and in cases where community differentiation is impossible. This image shows an area of the California coast approximately 36 kilometers north-west to South-east from San Simeon to Estero Bay.

of added information generally obtainable using color; and, (3) the absence of stereoscopic viewing. Owing to this reduction in aids to signature identification, certain specific difficulties were encountered: (1) individual tree crowns are not discernible on the ERTS-1 imagery, making it difficult to differentiate among hardwoods, conifers, and chaparral; (2) the absence of hue or color difference as an interpretative aid makes it difficult to differentiate between sagebrush and grassland (in some cases), and grassland and urban (almost all cases); and, (3) the absence of stereoscopic coverage makes it difficult in some cases to determine slope or aspect changes which often tend to indicate whether a vegetation community is sagebrush, chaparral or forest.

Nevertheless, there is sufficient information content in the ERTS-1 images for the construction of the reasonably detailed vegetation maps shown in Figures 6.2 and 6.3. The criteria on which the delineations and identifications were based include: (1) tone; (2) macro-textural differences (textural differences resulting from scattered agglomerations of trees or other features, as opposed to textural differences resulting from the arrangement and shape of individual plants); (3) shape (primarily in the case of agricultural fields which generally have rectangular shapes); and, (4) location (e.g., coastal, montane, valley, north-facing slope, etc.).

Upon completion of the vegetation maps, an evaluation of the ability to identify and delineate each of the vegetation communities was made. It is very difficult to quantify such an evaluation, so a five-step grading system was designed to describe the relative interpretability of each category. This grading system is illustrated in Table 6.7.

The table represents a vegetation community cross-evaluation, showing the relative ease with which one community can be differentiated from another community on ERTS-1 MSS band 5 (.61-.71 micron) imagery. The symbols on the left represent vegetation communities which are to be identified, and the symbols along the top represent the categories from which the community on the left must be differentiated. The composite category reflects the ease with which a given community can be correctly differentiated from all other communities together. Five ratings (++, +, -, --, and 0) were developed which are based on all the interpretation criteria shown in Table 6.6 (tone, texture, shape, and locational characteristics of the different vegetation communities). These evaluations are based only on the interpretation of the two test areas shown in Figures 6.2 and 6.3.

The table shows: (1) the relative ease with which each vegetation community could be differentiated from all other communities together; and, (2) how well each community could be differentiated from all the other communities or categories on a one-to-one basis. The results indicate that categories which were differentiated with the highest degree of accuracy (++ or + ratings) were: waterbodies (WB), barren ground (Ba), coastal strand (Sr), coastal salt marsh (Masm), grassland (G), scrub hardwood (Shw), and agriculture(A).

<u>Waterbodies</u> show up very clearly owing to low reflectance in

TABLE 6.7 INTERPRETABILITY OF VEGETATION CATEGORIES.

	Ba	Sr	Masm	Scs	Sc	G	WS	Shw	Fhw	Fco	R	Ag	U	Wb	Composite
Ba		+	++	+	++	+	++	++	++	++	++	+	-	++	+
Sr	+		++	+	++	-	++	++	++	++	++	++	--	++	+
Masm	++	++		+	+	++	++	+	+	+	+	++	++	+	+
Scs	+	+	+		-	-	-	+	+	++	+	+	-	++	-
Sc	++	++	+	-		++	+	--	--	-	+	+	++	++	-
G	+	-	++	-	++		-	++	++	++	+	+	0	++	+
WS	++	++	++	-	+	-		+	++	++	-	+	0	++	-
Shw	++	++	+	+	--	++	+		-	-	+	+	++	++	+
Fhw	++	++	+	+	--	++	++	-		--	-	+	++	++	-
Fco	++	++	+	++	-	+	-	-	--		+	++	++	++	--
R	++	++	+	+	+	+	-	+	-	+		-	++	+	-
Ag	+	++	++	+	+	+	+	+	+	++	-		+	+	+
U	-	--	++	-	++	0	0	++	++	++	++	+		++	--
Wb	++	++	+	++	++	++	++	++	++	++	+	++	++		++

++ Excellent differentiation (approximately 100%)

\+ Good differentiation (limited confusion)

\- Limited differentiation (often confused)

-- Poor differentiation (undifferentiable in most cases)

0 No differentiation

the red (.6-.7 micron) portion of the spectrum. The only features with which they could possibly be confused are: (1) irrigated fields which are also dark black in tone; and, (2) areas of salt marsh at high tide when they are inundated.

Barren ground shows up light grey to white in the case of beaches, areas cleared for construction, etc. It can be confused at times with some urban features, such as trailer parks, which have a large number of white or lightly reflective roofs close together. Barren ground, in the case of fallow or bare soil areas in agricultural areas, can be differentiated by the proximity to vegetated and irrigated rectangular fields.

Coastal strand generally shows up as a light grey concentration on or near the sandy coastline, and is rarely confused with other features.

Coastal salt marsh is generally dark grey and can be identified as a result of its proximity to rivermouths or location behind sand bars on the coast. In some cases, when chaparral or sage is located near sea level, misidentification is possible.

Grassland can generally be differentiated quite easily from all other vegetation communities, except concentrations of coastal sage and chaparral (which are found near sea level along the coast). The tone and texture of both grassland and urban areas is so similar as to render them undifferentiable.

Scrub hardwood can be differentiated quite easily on the basis of its grey-black tone, although at times it may be confused with chaparral or hardwood forests.

Agriculture can be easily differentiated on the basis of the essentially rectangular shape of the individual fields in this study area as well as a variation in tonal response (ranging from white for bare fields or dry forage crops to dark grey or black for recently irrigated fields). Portions of the area mapped on the imagery were anomalous in that small concentrations of agriculture were situated in the bottoms of ravines. Consequently, these agricultural areas were sometimes confused with riparian vegetation along the streams.

The categories that were more difficult to identify (rating -) and often confused are coastal sage (Scs), chaparral (Sc), woodland savannah (WS), hardwood forest (Fhw), and riaprain vegetation(R).

Coastal sage is generally light grey in tone and can be differentiated when there are large contiguous concentrations. However, when there are alternate concentrations of sage and chaparral on adret and ubac slopes, respectively, the resolution and lack of stereoscopic coverage makes it difficult to distinguish the divisions between these two types. Small concentrations, 10 acres or less, within the grassland areas are often difficult to identify and delineate because they tend to blend in with the light grey tone of the grassland.

Chaparral is hard to differentiate from shrub hardwood and hardwood forest owing to the similar grey to grey-black tonal response characteristic of all three.

Scattered trees in the woodland savannah community are not identifiable and the resultant grey tones are similar to the tonal responses of both the coastal sage and the grassland.

Hardwood forest is dark in tone and is indistinguishable from conifer forests. It is often similar to shrub hardwood and chaparral in tonal response.

Riparian vegetation can be differentiated owing to the sinuous and linear appearance on the imagery, but is hard to differentiate from agriculture in narrow valley bottoms. Riparian vegetation along small streams is unidentifiable owing to insufficient spatial resolution.

Coniferous forest is almost indifferentiable from hardwood forest owing to their similar black appearance on the imagery. It may be possible to differentiate between them based on locational factors such as: altitude in the case of digger pine (*Pinus sabiniana*); or proximity to the sea, in the case of cypress (*Cupressus sargentii*) and Monterey pine (*Pinus radiata*).

In summary, the preliminary evaluation of the ERTS-1 imagery for vegetation mapping indicates that there are certain problems resulting from insufficient spatial resolution and tonal range (on the black-and-white images). There is considerable overlap in the tonal signatures for many vegetation communities, and the use of texture as an interpretive aid is of minimal value. Nevertheless, it is possible to identify and delineate the more general categories of: (1) bare soil; (2) aquatic vegetation; (3) grassland; (4) scrub vegetation; and (5) forest vegetation. With the use of color composite images and multidate ERTS-1 imagery during the next reporting period, the identification and delineation accuracy should improve considerably. With the added information obtained from a color composite infrared image (similar to the one of the Monterey Bay area), it should be possible to differentiate sage brush (bluish-grey signature), chaparral (greenish-red signature) and hardwood forest (bright to dark red signature) on the basis of color or hue differences. On the MSS band 6 black-and-white imagery, they were often undifferentiable as a result of similar tonal response.

The added information gained by interpreting two or more dates of ERTS-1 imagery in concert may make further differentiation possible, since tonal responses of any two given categories can have a higher contrast ratio at different times. For example, it is almost impossible to separate urban areas on the July imagery from the surrounding grassland when the area is dry (high reflectance in all bands). However in December, when the grass is turning green, the interpreter should be able to make such differentiations.

6.5 RESEARCH TO BE CARRIED OUT DURING THE NEXT REPORTING PERIOD

1. Additional test areas will be chosen for vegetation mapping purposes in order to determine if the evaluations and problems reported on in this first report are representative.

2. U-2 photography acquired on the same date as the ERTS-1 imagery will be used to determine more accurately exactly what vegetation phenomena are responsible for a given signature on the ERTS-1 imagery (at the time of the completion of this report high altitude

imagery concurrent with ERTS-1 overflights was not available).

3. Color composites will be examined for both the test areas used during this first reporting period and for any additional test areas to determine what further information can be gained.

4. Quantitative estimates will be made of interpreter accuracy with respect to identifying vegetation communities and correctly delineate the boundaries of these communities.

5. The areal extent of the recent Bear Fire in the Los Padres National Forest (near Ojai, California) and the vegetation present in the area prior to the fire will be studied and mapped on the ERTS-1 imagery. The fire started August 22, 1972 and burned approximately 17,100 acres. This fire is particularly amenable to a study using ERTS-1 imagery because ERTS-1 coverage of the burn area occurred shortly before and after the dates of the fire. Possible areas of investigation may be: (1) determination of the areal extent of the fire damage; (2) damage assessment based on a comparison with vegetation conditions prior to the fire; (3) studies of vegetation regeneration on an 18 day basis; and, (4) disaster forecasting based on areas susceptible to probable flooding during the winter rains as a result of vegetation removal.

6. Inventories of the seaweed (kelp) along selected areas of the coastline will be made using band 6 (.7-.8 micron) to determine the utility of conducting large-scale inventories of kelp resources.

6.6 SUMMARY OF RESULTS

Land Use

1. Urban areas can be differentiated best on MSS bands 4 and 5.

2. Transportation linkages (highways, roads, airports) are most readily defined from MSS band 7.

3. Agricultural field boundaries are more clearly identified on MSS band 7.

Crop Identification (Bulk Color Composite Image)

1. Bare soil field conditions are identifiable with almost 100 percent accuracy (negligible errors of omission or commission).

2. It is difficult to identify particular crops on a single date because of signature overlap.

3. The crops with overlapping signatures have different growing cycles, which should serve as a basis for differentiation as ERTS-1 imagery for further dates becomes available.

Vegetation Mapping (MSS Band 5)

1. Barren land, Coastal Strand, Coastal Salt Marsh, Grassland, Scrub Hardwood, and Agricultural vegetation exhibit good differentiation.

2. Coastal Sagebrush, Chaparral, Woodland-Savannah, Forest Hardwood, and Riparian vegetation exhibit limited differentiation.

3. Confierous forest is difficult to differentiate.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

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DATE September 30, 1972

PRINCIPAL INVESTIGATOR Dr. R. N. Colwell

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ORGANIZATION University of California

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
1002181341	x	x	x	
1002181342	x	x	x	
100218134M	x	x	x	Hydrology, Lake, Delta
1002181401	x		x	
1002181402	x	x	x	
1002181403			x	Kelp
1002181406				Kelp
100218140R				Upwelling
100218140M	x	x	x	Upwelling
100218143R				Chaotic Cloud Pattern
100218143M				Chaotic Cloud Pattern
1003181751	x	x	x	
1003181752	x	x	x	Sediment
1003181753			x	Sediment
1003181754	x	x	x	Sediment
1003181755	x	x	x	Fault, Sediment
1003181756		x	x	Sediment
1003181757		x	x	
100318175M				Hydrology, Delta
1003181821			x	
1003181822	x	x	x	
1003181823			x	
1003181824	x		x	
1003181825	x	x	x	
1003181826		x	x	
1003181827		x	x	
100318184X				Chaotic Cloud Pattern
1004182301			x	
1004182302	x		x	
1004182305				Conifer
100418230R				Haze
100418230M	x		x	

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Chapter 7

USE OF ERTS-A DATA TO ASSESS AND MONITOR CHANGE IN THE SOUTHERN CALIFORNIA ENVIRONMENT (UN314)

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We at UCR are operating under the unfortunate situation of not having any ERTS-1 imagery for southern California (even though our fourth pass is starting this date). Because of this we are unable to make any assessment of ERTS-1 data at this time. Therefore, this report will include only an outline of our research designs, and a description of the preliminary work which has been completed.

7.1 ACCOMPLISHMENTS

Our stated objectives for investigations using ERTS-1 data fall into four broad categories. These are: (1) mapping of general land use patterns in both rural and urban areas, (2) monitoring land use change or evolution stimulated in southern California by population migrations and increased capital expenditures, (3) monitoring environmental pollution in the basins of southern California, and (4) developing models constructed to show "quality environment" as detectable from ERTS imagery.

7.1.1 Land Use Mapping and Land Use Change Monitoring

Preparations to use ERTS-1 data for land use mapping and land use change monitoring are underway in three diverse locations. These include: (1) agricultural land use mapping and automatic identification of crops in the Imperial Valley, (2) urban land use change in the northern Coachella Valley, and (3) analysis of complex land use patterns along coastal Orange and San Diego Counties. Preparation is also underway to gather "ground truth" data coordinated with ERTS-1 passes to be used both in assessing the validity of the visual record of air pollutants and regional atmospheric morphology.

a. Agricultural Land Use Mapping & Automatic Identification of Crops

The research objective of this project is to demonstrate the feasibility of monitoring cyclic crop production in a large regional area on a routine basis from satellites. The region selected for study is the Imperial Valley. The feasibility of identifying crops from satellites was demonstrated from 1969 Apollo IX imagery of the Imperial Valley by Claude Johnson who is presently directing the project. Monitoring the changes in some 8,000 fields every 18 days will necessarily require the aid of a computer. The system design calls for a human interpreter to indicate there is a crop or no crop in each of the fields. The identification of the crop type will be performed by the computer based upon the crop calendar, field size, soils type to support specific crops, regional specialization, and previous cropping. The availability of temporal crop data should enable us to obtain an objective of better than 90 percent accuracy of individual field crop identification by the fourth or fifth pass. Primary output will be a summary of acreage by crop type but the system design will provide the capability to produce thematic maps as a secondary product. Over 50 percent of the base map has been prepared for digital input to the computer and the design stage of the crop identification system has begun at this time.

b. Urban Land Use Change in the Northern Coachella Valley

Research objectives in the northern Coachella Valley involve the demonstration of ERTS-1 data to be a useful tool for monitoring urban-rural fringe land use change. The potential value of this test site is that the land use in settled areas is dominantly urban. The northern Coachella has as its economic base tertiary services associated with recreational and resort activities. The area has (since the late 1960's) experienced continual economic growth, which is manifested in a spectacular transformation of open space to urban land uses.

Previous remotely sensed records of land use in the Valley were acquired in 1967 and 1969. These will serve as a historical basis for comparison and change identification. As of this writing no decision has been made to utilize capabilities of our geographic information system. Both mapping and graphic display will be accomplished by non-automated methods.

c. Analysis of Land Use in Coastal Orange and San Diego Counties

Objectives of research using ERTS-1 data at this test site are threefold. First, the site extending from La Jolla Bay in the south to the channelized Santa Ana River in the north contains a diversity of land use types not found in the other locations. Coastal urban concentrations intimately intermingle with subtropical agriculture and recreational pursuits. Second, land uses in this coastal area are rapidly changing. The coastal plain and coastal foothills associated with the Peninsular ranges have been settled later and with less density than other stretches of the southern California coast. These areas now form foci for immigration and population growth. With this growth comes rapid change, and the opportunity to use ERTS data as a tool to record, monitor, compare and explain these landscape modifications. Third, preliminary investigations using NASA sponsored high-flight imagery indicate that visible air pollution produced in the greater San Diego metropolitan area cannot pass directly inland, eastward in response to general westerly atmospheric circulation because of local terrain arrangements. These pollutants appear to remain in the lower levels of the atmosphere, drift northward along the coast, and finally move eastward through the wind gaps formed by the Santa Margarita and San Luis Rey Rivers. Regional film coverage provided by ERTS should document the occurrence.

As was the case with previous research designs, effort has been concentrated on preliminary tasks in the absence of ERTS-1 imagery. Base maps are under preparation, ground truth information has been gathered in conjunction with the satellite overpasses and at other times. Land use and systematic enivronmental types of information have been collected for the entire area.

7.1.2 Regional Monitoring of Atmospheric Circulation & Atmospheric Pollution

Conventional aerial photography or small scale formats of weather satellites seldom provide information at intermediate scales useful for monitoring atmospheric circulation in a region the size of southern California. Research for this project is designed not only to visually monitor and record atmospheric pollution but to record and help explain the delicate energy transfers that occur at the interfaces of dissimilar desert and marine air masses.

A system for collecting as much recorded atmospheric data from all stations in southern California is now under development. Standard information including temperature, humidity and air pressure, as well as synoptic maps are gathered in the morning on each date there is an overflight. This information will then be compared to the ERTS-1 photography once it arrives. Pollution monitoring will be possible, with the interesting potential of matching a visual record with measurements of ground stations.

7.2 SIGNIFICANT ACCOMPLISHMENTS

None due to lack of ERTS-1 imagery.

Chapter 8

DIGITAL HANDLING AND PROCESSING OF ERTS-1 DATA (UN645)

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In this report we confine our description to the work of our group which is directed to the use of ERTS-1 data. With the launch of the ERTS-1 satellite, sets of multisensor data in an electronic format have become available to us. We have used three approaches in the analysis of such data:

Human Photo Interpretation

Electronic Image Enhancement

Automatic Data Processing

These three approaches complement one another and are all pursued within our study. In this initial progress report, however, we will describe only that part of our work which entails Electronic Image Enhancement.

Our work emphasizes man-machine interaction rather than bulk processing of data. It uses as a central processing element a digital computer and thus the development or use of data-processing algorithms becomes principally a problem in computer software development. Our interest centers on the questions of multisensor data combination and electronic image enhancement.

Two facts determine the nature and extent of our work for this brief reporting period since the start of the project: (1) the type of data available from ERTS-1 is somewhat different from that originally planned because of the unavailability of RBV data; and, (2) the time lag in our receipt of data in a Computer Compatible Tape form has resulted in no data being available to us in digital form at the time of this writing.

Our report divides into three parts: firstly, a very brief description of the processing facility available to us for this work with emphasis on features of that facility which are specially valuable for work on ERTS data; secondly, a short description of the set of programs already available to us for work on ERTS data; finally, a description of the work done which our group has performed to date on NASA supplied data, together with comments on problems which will be considered in the immediate future.

8.1 DATA PROCESSING FACILITY

The digital image processing facility available for our work is shown in diagram from in Figure 8.1. The facility is operational, with the exception of the data link to the CDC 6400 digital computer at the Berkeley Computer Center.

Two other hardware improvements are underway which will increase the usefulness of the facility for work on ERTS data. An improved high resolution black-and-white display has been acquired and has been interfaced to the digital computer. One significant advantage of this

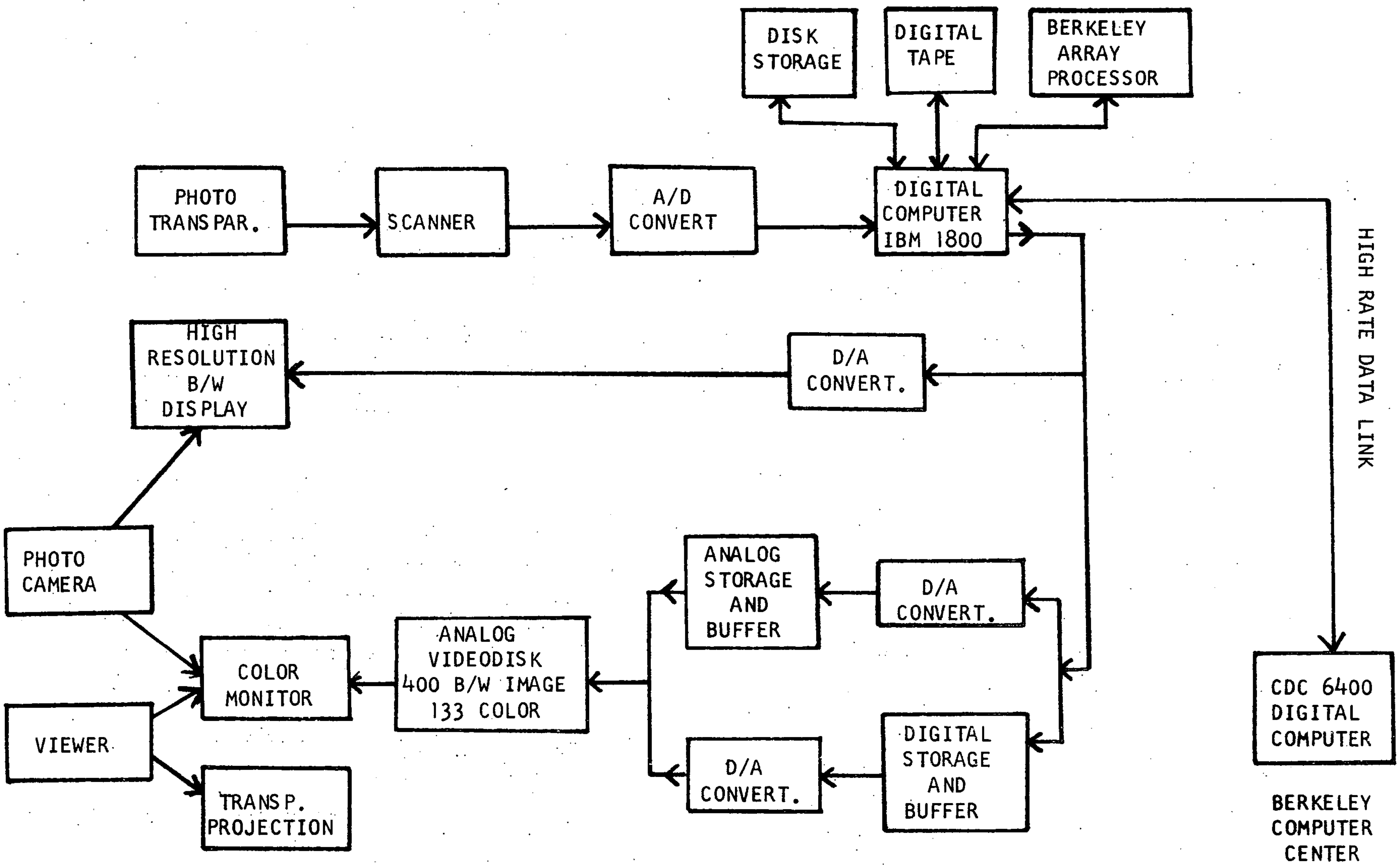

Figure 8.1 Schematic representation of our Digital Image Processing Facility

display is that it will make possible high quality color photography by the use of a suitable cathode ray tube and color filters.

A second hardware improvement results from our acquisition of an additional disc storage unit for facilitating rapid access. We are currently quite limited in the amount of rapid access storage available. This creates difficulties in the convenient processing of multispectral data. The problem will be alleviated by this new head-per-track digital disc with an additional 9 million bits of storage. A noteworthy feature of our facility for work on ERTS data is the large analog video storage available which makes possible extremely rapid comparison of different enhancement algorithms without resorting to photography. Another interesting feature is the scaling available in our digital storage and buffer facility. This makes possible the inspection of subimages of very small size (64 by 64 picture elements) under extreme magnification and with perfect registration from spectral band to spectral band.

8.2 PICTURE PROCESSING PROGRAMMING SYSTEM AND UTILITY PROGRAM

Due to the large number of specific operations of interest in our work it is necessary to provide a framework for the organization of our user oriented image processing programs. To this end an image processing system is being developed, consisting of four components: (1) processing subroutines, (2) user programs, (3) a monitor, and (4) a disc update program.

The processing subroutines perform the actual picture processing, including such tasks as filtering and display. Each user program consists of a sequence of statements used to cause the execution of a sequence of processing subroutines. The monitor interprets the user program, stores the information contained in the user program, allocates appropriate storage space for data files, and initiates execution of processing subroutines. The disc update program adds, to the monitor portion of the discs, all required information about a processing subroutine newly added to the system. One version of this programming system is operational. Some additional features for increased flexibility of use in an interactive mode are being developed.

These general utility subroutines are necessary building blocks in the design of user-oriented programs. A listing of some of the programs now available will illustrate the type of operations these programs perform. In use, after the description has been given, a set of parameters specifies completely the operation. To determine the nature of the program the user may obtain a description of the operations performed by typing a question mark after the title of the program. A listing of programs available as of August 15, 1972 is given in the appendix.

8.3 PRELIMINARY WORK USING NASA SUPPLIED DATA

By the end of the present reporting period we had received from NASA the following data:

1. A set of seven preflight calibration 9-track computer

compatible calibration tapes.

2. Black-and-white 70 mm positive transparencies covering three areas of California of interest to our integrated study. These photographs correspond to orbits over the State of California on July 25, 26 and 27, 1972. Some of the photographs are for all 7 spectral bands (the 3 RBV bands and the 4 MSS bands), although a number of them are for RBV data only.

3. Two color composites of bands 4, 5, and 7 for two adjacent areas of the State of California, for the orbits of July 26, 1972. We also requested and received from NASA up-to-date information on computer compatible tape formats.

The tasks which we performed on the above data included the following:

1. Reading and display of the NASA calibration tape.

2. Subsampling the data to display a larger geographic area at the cost of a loss in resolution. Since we are limited to a display that employs no more than 512 x 512 picture elements (pel), we have to work on a portion of the original NASA data set. We can increase, within some limits, the working geographical area by trading off the spatial resolution of the area displayed.

3. Development of a simple filing system for 70 mm positive transparencies. These transparencies constitute for us a convenient file for perusal and for the determination of subsequent requests for computer compatible tape. A master file with some description of image quality, has been established for images of interest to our work.

4. Selection of a basic image file size for the processing, enhancement and reformatting of NASA data: programs have been written for reformatting NASA data to a form more convenient for our subsequent work. Files of 512 x 512 pel will form our working image file. A program to generate 4 MSS image files from NASA supplied tape has been written.

5. Some basic line enhancement and boundary removal algorithms have been written and tested on digital data provided by the Forestry Remote Sensing Laboratory. This digital data was obtained by digitizing high flight photography.

6. A substantial number of specific enhancement programs have been or are being written. We expect to illustrate the application of such programs to ERTS-A data in our next progress report. Although our work emphasizes digital processing of data and interactive work using a color display, the documentation of our work requires the use of color photography. A significant effort is being made to establish the proper combination of digital processing techniques, picture taking and subsequent processing of color which will give a good control of our color photographic products.

APPENDIX

THE PROGRAMS ON THE PICTURE PROCESSING SYSTEM INCLUDE:

EXIT : EXIT RETURNS DATA TO TASK MONITOR.

RELSF : RELSF IS A SYSTEM SUBROUTINE USED FOR RELEASING FILE SPACE.

SYSTM : SYSTM IS A SYSTEM SUBROUTINE FOR TYPING OUT THE PRESENT STATE OF THE SYSTEM.

TRACE : TRACE SETS UP THE SYSTEM ERROR MASK WORD.

CHKPR : CHKPR FINDS THE MAXIMUM, MINIMUM, AND AVERAGE SIGNAL STRENGTHS (GREY LEVELS) OF A PICTURE.

FFT : FFT DOES A FORWARD FOURIER TRANSFORM ON A PICTURE FILE.

FLTML : FLTML TAKES A COMPLEX PICTURE AND MULTIPLIES IT BY AN ISOTROPIC FILTER.

FLTST : FLTST SETS UP A VARIABLE WORD (COMPLEX OR REAL) FILE ON THE DISC.

FRAME : FRAME TAKES A SECTION OF PACKED PICTURE FILE AND PUTS IT ANYWHERE IN ANOTHER PICTURE.

FRAMS : FRAMS INITIALIZES A PACKED PICTURE FILE FOR THE FRAME PROGRAM. IT CAN BE USED TO CLEAR CERTAIN PICTURE ELEMENTS TO CONSTANTS.

HSTCL : HSTCL TAKES THE HISTOGRAM OF A PICTURE AND GENERATES A TABLE. IF THE PICTURE IS PASSED THROUGH THIS TABLE THEN THE TRANSFORMED PICTURE WILL HAVE A FLAT HISTOGRAM.

HSTGR : HSTGR GENERATES THE SIGNAL STRENGTH (GREY LEVEL) HISTOGRAM OF A FILE AFTER SCALING THE DATA IN THE FILE FROM 0 TO 225. THE HISTOGRAM IS STORED IN A FILE.

IFT : IFT DOES AN INVERSE FOURIER TRANSFORM ON A PICTURE FILE.

INTGL : INTGL FINDS A FUNCTION OF TWO VARIABLES GIVEN THE GRADIENT OF THAT FUNCTION AND THE VALUE OF THE FUNCTION AT ONE POINT.

MAGNT : MAGNT COMPUTES THE MAGNITUDE OF THE FOURIER TRANSFORM.

PACK : PACK TAKES A PICTURE FILE OF SIZE 256 OR LESS IN 16 BITS/POINT FORMAT AND PACKS IT INTO A PICTURE OF 8 BITS/POINT.

PICPK : PICPK TAKES BULK DATA AND CREATES A 512 x 512 ELEMENT PICTURE.

PRDWX : PRDWX TAKES THE PARTIAL DERIVATIVE WITH RESPECT TO X OF A PICTURE.

PRDWY : PRDWY TAKES THE PARTIAL DERIVATIVE WITH RESPECT TO Y OF A PICTURE.

PRINT : PRINT PRINTS OUT DISC INFORMATION IN DECIMAL INTEGER FORM.

SQUARE : SQUARE GENERATES A PICTURE FILE HAVING SQUARES WITH GREY LEVELS FROM 0 TO 255.

TAPER : TAPER CAN BE USED TO STORE OR RETRIEVE UNPACKED PICTURE FILES ON TAPE.

TESTD : TESTD GENERATES A CHECKER BOARD PATTERN IN AN UNPACKED FILE.

VIBE : VIBE DISPLAYS A PACKED PICTURE OF ANY SIZE EXPANDED TO THE VIBE.

RDTPE : RDTPE READS PICTURES FROM A TAPE. ONE LINE IS READ FROM EACH RECORD. LINES MAY BE 64, 128, 256, or 512 ELEMENTS IN LENGTH.

Chapter 9

USE OF ERTS-1 DATA IN THE EDUCATIONAL AND APPLIED RESEARCH PROGRAMS OF THE AGRICULTURAL EXTENSION SERVICE (UN326)

Co-investigator: William E. Wildman
Agricultural Extension Service, Davis Campus

9.1 PROBLEMS IMPEDING PROGRESS OF THE INVESTIGATION

The extreme density of the 70 mm negatives of imagery from July 25 to July 29 makes them unusable for reproducing enlargements. We are having to make our own negatives from the positives provided. For our study, it is necessary to make paper enlargements for distribution to county farm advisors.

We need 9.5 x 9.5 inch positive bulk imagery. Our original standing order did not include this because we thought we were going to receive routine precision imagery in this size. The standing order has been changed to obtain bulk 9.5 inch imagery in future passes.

Our investigation will naturally get underway rather slowly because of the need to work with a great number of people.

9.2 ACCOMPLISHMENTS DURING THE INITIAL PERIOD

Eight training workshops have been scheduled in northern California counties and will be held in the second reporting period (October, 1972). Processing of reproductions is taking place in our Visual Aids Unit in preparation for these workshops. County Extension Offices will be routinely provided with black-and-white 9.5 inch prints in one wave band (MSS-5) which provides the greatest contrasts between crop and forest land uses. Other bands will be available on an order basis. Color slides of color infrared enhancements as they become available will also be provided to counties. We are attempting to make our own color infrared enhancements on a diazo type machine and if successful will be able to provide a much better basis for study by the farm advisors. (See page 9-3 and envelope included at back of this report.)

9.3 PRELIMINARY EVALUATION OF ERTS-1 IMAGERY

Broad agricultural land uses stand out strongly on ERTS-1 images, particularly the color infrared enhancements. Rice areas can be picked out readily because of their large size and their dark tones on red band images (2 or 5) and bright red color on color infrared enhancements. Orchard and vineyard areas show up as less distinctive because some bare soil shows between the tree or vine rows. A large area of very distinctive square 160 acre fields shows up in western Fresno County. This is an area cropped entirely in field crops, mostly alfalfa, cotton safflower, sugar beets, barley, and wheat. Distinctive parallel light and dark lines can be seen in many of these 160 acre fields, mostly oriented N-S, but a few E-W. Some of these result from light and dark soil patterns associated with recency of sprinkler irrigation. Others seem to be the result of recent plant growth influenced by irrigation. This appearance will be clarified during the next reporting period after study with the farm advisors.

AGRICULTURAL EXTENSION SERVICE

UNIVERSITY OF CALIFORNIA

Date: October 16, 1972

Department of Soils and Plant Nutrition

DAVIS, CALIFORNIA

To: Robert N. Colwell
Space Sciences Laboratory

From: William E. Wildman William E. Wildman
Title: Extension Soils Specialist
Re: Type I, Periodic Report Number 1
Supplement to Section d.

PREPARING COLOR ENHANCEMENTS WITH A DIAZO MACHINE

Our Visual Aids Specialist, Hays Fisher, has developed a quick, inexpensive, and very effective means of producing color enhancements directly from 70 mm or 9.5 inch bulk black and white positives. A diazo machine is used to make colored positives in the green, red, and infrared wave bands. The three clear acetate positives are then taped to a cardboard overhead transparency mount in common register to make a simulated false color infrared image. The image can then be studied directly, viewed with an overhead projector, or photographed to make slides.

A wide range of colors is available in acetate stock. For the first attempts at preparing color enhancements, we made 9.5 inch positives of yellow, magenta, and cyan for the 4 (green), 5 (red), and 7 (infrared) bands of the MSS, respectively. The resulting enhancements were dull and somewhat disappointing in range of color tones discernible. Next, we tried red positives for the red band and blue for the infrared band, retaining yellow for the green band. After some experimentation to determine proper density, we arrived at settings which gave satisfactory color balance and detail. These settings allowed us to see about 10 shades on the gray scale for the red and blue positives, and 7 to 8 shades for the yellow positives.

The advantages of this color enhancement method are several. The most important is the faithfulness of reproduction of the original imagery. Since it is a contact process, much better detail is retained than in a process requiring projection. In addition, registering of the color separations is easy as long as the original transparencies register properly. We have found one case, image 1004-18221, in which the 5 and 7 bands do not register.

The process is rapid and inexpensive. A color enhancement can be prepared in a few minutes from stock costing a few cents a sheet. Considerable flexibility in use of different colors for special false color effects is possible.

We have had some difficulty in standardizing the exposure and development times. We have found it necessary to place a voltage regulator in the line supplying the diazo machine to prevent voltage fluctuations which caused variations in exposure and development times using the same image. To get best results with our diazo machine, we have to treat each image separately, and arrive at the proper density by trial and error. Use of a densitometer on the original positives might facilitate proper exposure of the diazo sheets. In addition, more sophisticated diazo machines than our relatively inexpensive model may have better control of these factors.

WEW:yw

CC: Gordon Huntington

C

Chapter 10

USE OF ERTS-1 DATA IN IDENTIFICATION, CLASSIFICATION, AND MAPPING OF SALT AFFECTED SOILS IN CALIFORNIA (UN327)

Co-investigator: Gordon L. Huntington
Department of Soils and Plant Nutrition, Davis Campus

This investigation was designed to use the interpretive skills of specialists experienced in recognizing and delineating salt affected soils on aerial photographs. The initial studies of ERTS-1 data received to date, covering the period July 25-27, 1972, between Lat. N36° 30' to N40° 45' within the Great Valley of California, have been directed toward familiarizing the specialists with the character, appearance, and nature of the imagery, the limits of resolution, and the identification of known surface features on the land. Overlays for the 9.5 inch positive transparencies to provide quick location and local control are being prepared to study the imagery systematically in relation to known, mapped areas of salt affected soils. Lack of precision imagery is impeding their preparation and the general study. "Eyeball" preparation of overlays for the distorted bulk processed imagery is time consuming and inexact.

The location of the format centers of imagery received, as determined by use of the registration marks and transferred to USGS 1:250,000 maps, does not entirely agree with that location given in the alphanumeric notations. MSS images 1002-18134 and 1003-18175 show plotted format centers that are within ± 0.5 minute of the given latitude, but are

3.5 minutes west of the given longitude.

10.1 ACCOMPLISHMENTS DURING THIS REPORTING PERIOD

Imagery covering the central part of the Great Valley of California has been closely studied and field checked from the air. A small plane flown at about 5000 feet altitude from Davis to Five Points and return under conditions of good visibility was used as an observation platform. This region was covered by MSS images 1002-18134 and 1003-18175. Bulk B&W 9.5 inch positive transparencies were used. To facilitate handling during observation, the transparencies were protected by plastic sleeves.

MSS bands 5 and 7 provided the most useful imagery for aerial observation. Most prominent ground features observed in flight were clearly and easily located on the transparencies, and the ground path of the flight was easily monitored across the imagery. Many lesser surface features not identified, or identified with uncertainty, during pre-flight examination became satisfactorily evident. The perception and confidence of the observers with the imagery was markedly improved by this exercise. During the course of the flight, many low and high oblique colored slides of the terrain were taken for later detailed, spot studies of the ERTS imagery. These pictures were taken mainly over areas known to have saline-alkali affected soils.

Later study of the obliques and the ERTS imagery under low power (8X) magnification clearly identified the very light, irregularly shaped, discontinuous tonal patterns of "scald" spots indicative of soils that are surficially alkali (sodic) or saline-alkali affected. These are best identified on band 5 images, and are most easily seen on unreclaimed, areas of salt affected soils. They are more subtle, but recognizable on partially reclaimed and cropped lands.

During the next two month period, there will be continued study of images received to confirm "scald" spot recognition, and to determine if possible, the recognizable extent of salt affected soils in the Great Valley as seen on the images and checked against mapped areas shown in existing soil survey reports. Attention will be paid to the west side of the Sacramento Valley and the salt affected soils in the rice lands. If infrared color transparencies are received, the color-tonal signatures for subsurface alkali or salt accumulation will be investigated.

10.2 PRELIMINARY EVALUATION OF ERTS-1 IMAGERY

The "scald" spots are important surface features to use in sleuthing the extent of salt affected soils, particularly saline-alkali soils. These spots are areas on the soil surface too saline or saline-alkali to support significant plant growth. They may be helpful, but are less prominent on saline soils in California. In addition, the irregular, light-dark patterns can be used to class salt affected soils on the basis of percent of surface area affected. Care must be exercised to distinguish these spots from droughty sand streaks or exposed light colored subsoils in leveled lands that are not salt affected. The distinctions thus far are not infallible, but knowledge of the landforms involved is helpful.

The most extensive area of these spots were observed in the basin-rim lands on the east side of the San Joaquin Valley in Fresno, Madera, and Merced Counties. They are best observed on image 1002-18145-5, are less clear on band 4, and least evident on bands 6 and 7.

These blemishes on the land range in rough diameter from 1 or 2 feet up to as much as 400 to 500 feet. Commonly they are 2 to 5 feet up to about 100 feet across. They are very irregular and usually exist in clusters separated by similar sized, vegetated areas of soils not surficially salt affected. It was noted that except for large salt playas, the spots observed on the images were clusters of real "scald" spots. The limit of visibility thus far observed was for clusters about 300 feet in diameter in which the real "scald" spots made up about 50 percent of the area. One cluster observed was scattered over a 20 acre area, but the real spots comprised only about 5 acres in summed extent.

The detectable clusters on the band 5 image are most easily seen on the unreclaimed lands. The general shape and extent of the clusters can be identified. On partially reclaimed land in field crops, at the lower limit of visibility, they appear as faint, irregular light spots with a diffuse outer boundary.